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NASA/MSFC FY-84 Atmospheric Processes Research Review

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Summary of a program review held in
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National Aeronautics
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**Scientific and Technical
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1984

ACKNOWLEDGMENTS

The productive inputs from the participants in the NASA/MSFC FY-84 Atmospheric Processes Research Program Review contributed very much to the success of the review. This report provides the opportunity for everyone to become better acquainted with the work of other investigators and to see how the research relates to the overall objective of NASA's Atmospheric Processes Research Program. Appreciation is expressed to all those who provided inputs to the review. The NASA Headquarters and Marshall Space Flight Center program managers trust that the information will provide a better frame of reference from which to proceed with the next year's research activities.

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PREFACE

Each year NASA supports research in various disciplinary program areas. The coordination and exchange of information among those sponsored by NASA are important elements of each program. The Office of Space Science and Applications, Earth Science and Applications Division, via Announcements of Opportunity (AO), Application Notices (AN), etc., invites interested investigators throughout the country to communicate their research ideas for consideration. The proposals in the Atmospheric Processes Research area selected and assigned to the NASA Marshall Space Flight Center's (MSFC's) Atmospheric Sciences Division for technical monitorship, together with the research efforts included in the MSFC Research and Technology Operating Plan (RTOP), are the source of principal focus for the NASA/MSFC FY-84 Atmospheric Processes Research Program Review.

The principal purpose of the review and summary report is to provide those having atmospheric research activities sponsored by NASA, and assigned to MSFC's Atmospheric Sciences Division, an opportunity to communicate their accomplishments and future plans. In addition, the review provides NASA Headquarters and MSFC Research Program Managers with a current status report plus suggestions for future research to use in developing the program. The principal managers involved are Mr. John Theon, Dr. James Dodge, and Dr. Robert Curran, Atmospheric Dynamics and Radiation Branch, Earth Science and Applications Division, OSSA, and Dr. William W. Vaughan, Atmospheric Sciences Division, Systems Dynamics Laboratory, MSFC. Ms. Fay Porter served as coordinator for the research review.

The two main areas of focus for NASA/MSFC's Atmospheric Research Program are: (1) Global Scale Processes (Geophysical Fluid Processes, Satellite Doppler Lidar Wind Profiler, and Satellite Data Analyses) and (2) Mesoscale Processes (Atmospheric Electricity (Lightning), Ground/Airborne Doppler Lidar Wind Measurements, and Mesoscale Analyses and Space Sensors).

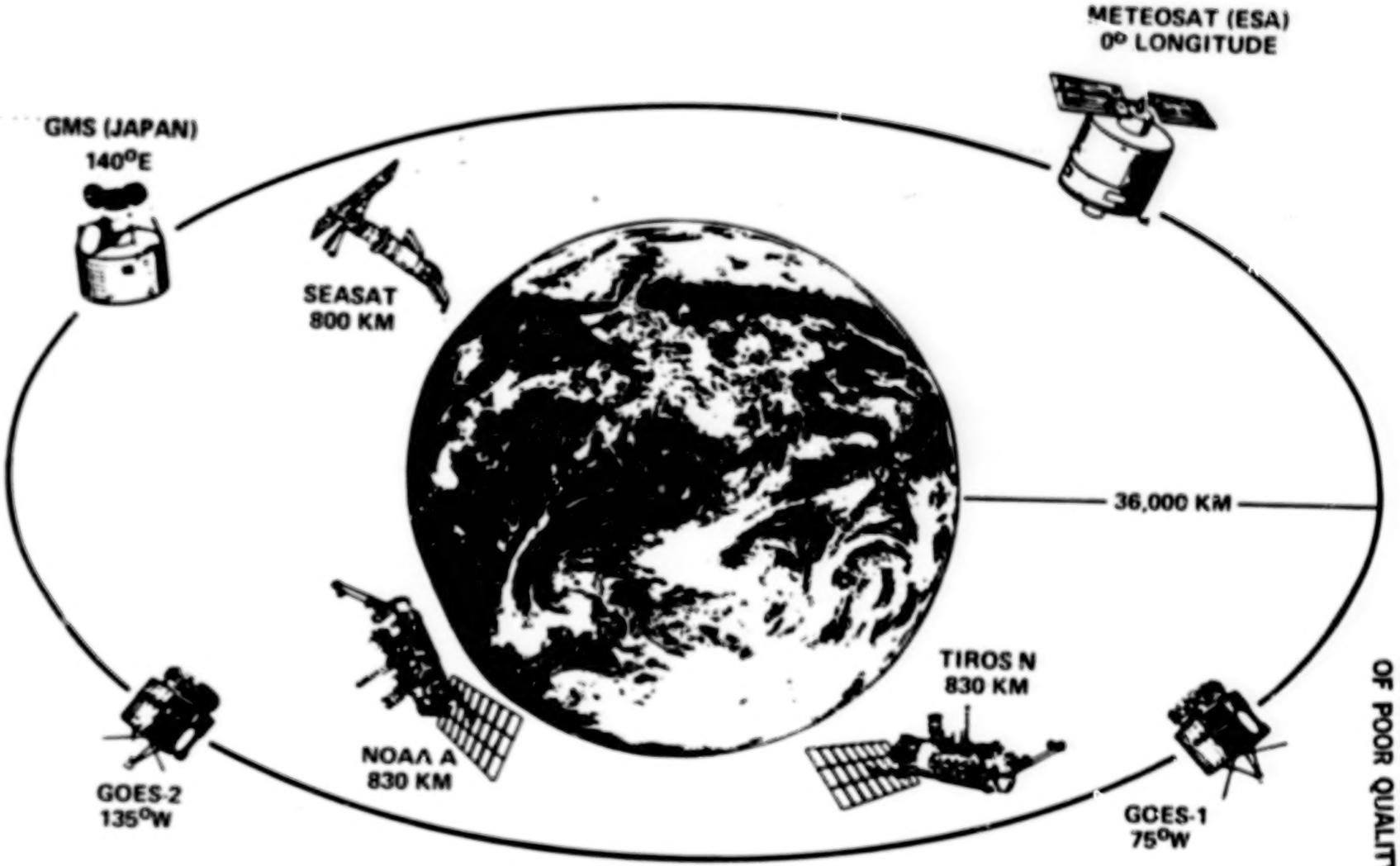
It is recognized that the scopes of individual research efforts comprise a wide range. Some are very modest or have been underway for only a short period of time, whereas others are relatively large and involve several years of activity. However, the opportunity to learn what each investigator is doing and to develop the team relationship necessary for a meaningful research program were considered most important. The technical aspects of the research efforts are stressed with respect to accomplishments and rationale for the recommendations on the coming year's research. It is toward this goal that this summary report has been developed.

Recipients of this report are encouraged to communicate directly with the respective investigators regarding scientific and technical matters or questions they might have on the research efforts. Any recommendations or suggestions concerning the program will be welcomed.

William W. Vaughan, Chief
Atmospheric Sciences Division
Systems Dynamics Laboratory
NASA, Marshall Space Flight Center

I. GLOBAL SCALE PROCESSES RESEARCH

ATMOSPHERIC SCIENCES DIVISION



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GLOBAL SCALE ATMOSPHERIC PROCESSES RESEARCH PROGRAM

PROGRAM ORGANIZATION AND GOALS

NASA HEADQUARTERS

OSSA

MSFC

GLOBAL SCALE ATMOSPHERIC PROGRAM

DATA ACQUISITION AND ANALYSIS

GOALS:

1. COMBINE DATA FROM REMOTE SENSORS TO CONVENTIONAL DATA TO MAXIMIZE DATA CONTENT AND UTILIZATION.
2. STUDY WEATHER SATELLITE DATA TO INVESTIGATE CYCLONE SYSTEMS.
3. DEVELOP MODELS OF TURBULENCE TO DETERMINE VELOCITY PROFILES.
4. STUDY MOISTURE BURST PHENOMENA EMANATING FROM THE INTERTROPICAL CONVERGENCE ZONE (ITCZ).
5. DIAGNOSE THE ENERGY STATE OF EXTRATROPICAL CYCLONES.
6. GENERATE MODELS TO ACCOUNT FOR WELL DEVELOPED BAROCLINIC CYCLONE WAVES.
7. STUDY PHYSICAL PROCESSES THAT DEVELOP, MAINTAIN AND DECAY THE SOUTH PACIFIC CONVERGENCE ZONE AND ITS CLOUD.
8. USE SATELLITE DATA TO MAKE LONG–TERM PREDICTIONS OF GLOBAL WIND FLOW AND CLOUD MOVEMENT OVER OCEANIC AREAS.

SATELLITE WEATHER DATA TECHNOLOGY

CONVENTIONAL DATA UTILIZATION

PARTICIPANTS

IN–HOUSE	UNIVERSITIES	OTHER
CIVIL SERVICE USRA SCIENTISTS SUPPORT CONTRACTORS	TAMU, PENN STATE, PURDUE CITY UNIVERSITY OF NY, UNIV OF IL. YALE UNIVERSITY, UNIV. OF WIS.	NOAA NCAR GSFC NSSFC ESSA NESDIS NWS ETC.

ORGANIZATION: ED42	MARSHALL SPACE FLIGHT CENTER GLOBAL SCALE PROCESSES RESEARCH PROGRAM NASA/MSFC FY-84 ATMOSPHERIC PROCESSES PROGRAM REVIEW	NAME: G. H. FICHTL
CHART NO.:		DATE: APRIL 1984

ATMOSPHERIC PROCESSES PROGRAM ELEMENTS

- SUPPORTING RESEARCH AND TECHNOLOGY
- GEOPHYSICAL FLUID PROCESSES EXPERIMENTS
- SATELLITE DOPPLER LIDAR WIND PROFILER
- SHUTTLE ATMOSPHERIC SCIENCE EXPERIMENTS

ORGANIZATION: ED42	MARSHALL SPACE FLIGHT CENTER GLOBAL SCALE PROCESSES RESEARCH PROGRAM NASA/MSFC FY-84 ATMOSPHERIC PROCESSES PROGRAM REVIEW	NAME: G. K. FICHTL
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SUPPORTING RESEARCH AND TECHNOLOGY

- **THRUSTS**
  - SATELLITE DATA ANALYSIS TO UNDERSTAND ATMOSPHERIC PROCESSES AND DEFINE FUTURE SENSOR REQUIREMENTS
  - ACCOMPLISH LABORATORY, THEORETICAL, AND NUMERICAL MODELING STUDIES TO SUPPORT RESEARCH/FLIGHT PROGRAM DEVELOPMENTS
  - IDENTIFY NEW SCIENTIFIC THRUSTS FOR PAYLOAD/EXPERIMENT CONCEPT DEFINITION
  - SUPPORT LOWER AND UPPER ATMOSPHERE INPUT DEVELOPMENTS FOR MAJOR MSFC PROJECTS
- **COMPONENTS**
  - TROPIC/SUBTROPIC COUPLING
    - SPCZ/FGGE – VINCENT/ROBERTSON
    - MOISTURE BURSTS – THOMPSON/McGUIRK
  - CYCLONE DYNAMICS/LATENT HEAT EFFECTS
    - COMMA CLOUDS – SALTZMAN/TANG
    - OBJECTIVE ANALYSIS – ACHTEMEIER/KIDDER
    - ENERGETICS – SMITH/ROBERTSON
    - INSTABILITIES – CLARK
    - CLOUD PARAMETERIZATION – ROBERTSON, CLARK
  - PLANETARY SCALE PROCESSES
    - INDEX CYCLE – DUTTON/CLARK
    - LONG WAVE DYNAMICS – CLARK
    - RADIATION BUDGET – DUTTON

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GEOPHYSICAL FLUID PROCESSES EXPERIMENTS

- **THRUST**
  - DEFINE EXPERIMENTS AND GFFC MODIFICATIONS FOR FOLLOW–ON MISSIONS
  - CONDUCT SUPPORTING RESEARCH
  - PROVIDE SCIENTIFIC SUPPORT FOR GFFC EXPERIMENTS
- **COMPONENTS**
  - GFFC SCIENCE–HART ET. AL.
  - GFFC INSTRUMENT/SL–3 INTERFACES – LESLIE
  - SPIN–UP – LESLIE
  - REGIME DIAGRAMS (AGCE) – FOWLIS
  - BAROCLINIC WAVES – ANTAR, MILLER

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SATELLITE DOPPLER LIDAR WIND PROFILER

- **THRUSTS**
  - DEFINE GLOBAL AEROSOL BACKSCATTER REQUIREMENTS FOR SYSTEM DESIGN
  - CONDUCT SIMULATION STUDIES FOR PERFORMANCE AND DATA MANAGEMENT DEFINITIONS
  - ACCOMPLISH AIRBORNE SUPPORTING SENSOR PERFORMANCE AND RESEARCH EXPERIMENTS
- **COMPONENTS**
  - AEROSOL BACKSCATTER – JONES ET AL
  - IR BACKSCATTERING – BOHREN
  - REQUIREMENTS/SIMULATION – EMMITT
  - SYSTEM STUDIES – BERANEK
  - CO_2 BACKSCATTER EXPERIMENT – FITZJARRALD, ET AL

ORGANIZATION: ED42	MARSHALL SPACE FLIGHT CENTER GLOBAL SCALE PROCESSES RESEARCH PROGRAM NASA/MSFC FY-84 ATMOSPHERIC PROCESSES PROGRAM REVIEW	NAME: G. H. FICHTL
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SHUTTLE ATMOSPHERIC SCIENCE EXPERIMENTS

- THRUSTS
  - CONDUCT SCIENCE ISSUES REVIEWS AND SENSOR COMPLEMENT ANALYSES
  - DEVELOP PROTOTYPE FOR AIRBORNE TESTS OF MULTISPECTRAL ATMOSPHERIC MAPPING SENSOR
  - SUPPORT SCIENTIFIC ASPECTS OF MSFC's EARTH OBSERVATION MISSIONS (EOM) ASSIGNMENTS
- TOPICS
  - SCIENCE ISSUES/EXPERIMENT CONCEPT – ROBERTSON, ET AL
  - LARS CONCEPT – VAUGHAN, ET AL

I.A. GEOPHYSICAL FLUID PROCESSES

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THEORETICAL ANALYSES OF BAROCLINIC FLOWS

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Work has been completed on the three-dimensional, linear stability analysis of the baroclinic Hadley cell. These analyses lead to significant new theoretical results concerning the symmetric modes of baroclinic instability. Most important of these, is the discovery that the symmetric modes occur at far lower values of the Richardson number than has been previously anticipated. This conclusion was obtained from growth rates results. It was also found that these values of the Richardson number are not very sensitive to moderate values of the Prandtl number. This work also clarified the problem of the horizontal tilt of the symmetric waves. It was found that the most unstable symmetric modes are inclined at an angle to the zonal direction, but that angle was extremely small. Due to the significance of these results, I was invited to present my work at a symposium on double diffusion convection (this symposium is reviewed in J.F.M., 138, 1984). Also this work was published in the December 1983 issue of the Journal of Fluid Mechanics.

Work has been completed on the numerical modelling of the baroclinic flow between two rotating concentric spheres. The analysis models axisymmetric flow in the AGCE configuration. A mixed Spectral-Finite Difference method was used, which resulted in moderately fast convergence rates. Results were obtained for a limited number of parameter values. This work led to a dissertation for the PhD degree in Engineering Science and Mechanics at the University of Tennessee Space Institute.

Work is proceeding on the code development to solve the strongly nonlinear stability problem for the Eady basic state. No results have yet been obtained. However, we anticipate the successful running of the code in the very near future.

I have not received any supporting funds from NASA towards the tasks described above for FY-84. The University of Tennessee Space Institute has been extremely generous in its financial support of this research.

The plans of FY-85 is to complete and extend the third task element described above.

Publications prepared since June 1983:

1. Three-Dimensional Baroclinic Instability of a Hadley Cell for Small Richardson Number. Journal Fluid Mech., 137, 423-445, 1983.

2. Numerical Model of the Axisymmetric Flow in a Heated Rotating Spherical Shell, PhD Dissertation by Michele Macaraeg, 1984.

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TITLE: Theoretical Flow Regime Diagrams for the AGCE

INVESTIGATORS: William W. Fowlis and Timothy L. Miller
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SIGNIFICANT ACCOMPLISHMENTS:

The major criterion for the design of the AGCE is that it be possible to realize strong baroclinic instability in the apparatus. To ensure that this criterion is met, accurate calculations to determine the transitions between the stable and unstable flow regimes must be performed for proposed AGCE apparatus configurations. These calculations are being carried out by first determining the axisymmetric basic states with a fully nonlinear, two-dimensional, numerical model and then determining the stability of these basic states to zonal perturbations with a linear numerical model.

The numerical models have been developed and tested. The codes in cylindrical form were checked by comparing their predictions with the experimental regime diagram for the differentially heated and rotating cylindrical annulus flows. The spherical terms were checked by comparing numerical predictions with accurate laser-Doppler measurements of homogeneous spin-up in a sphere.

Although it has been decided that the AGCE configuration will consist of a low viscosity silicone fluid contained between two hemispheres with a rigid boundary at the equatorial plane, this still leaves various possibilities with respect to, the radii of the hemispheres, the presence of a high latitude boundary and the boundary temperature distributions. Axisymmetric basic state flows have been computed for fifteen different configurations. Some of these flows have exhibited two-dimensional instability and unsteadiness which presents problems for azimuthal stability analysis.

A spherical annulus configuration which allows only steady basic state flows was chosen for the first set of stability analyses. The most significant accomplishment of FY-84 is that baroclinic instability has been found for this configuration and that the

few results obtained to date suggest a regime diagram very different from the cylindrical annulus regime diagram.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The spherical regime diagram is being completed. Delays have occurred due to slow convergence of the stability code. This code converged rapidly for the cylindrical annulus studies. We are investigating whether the slow convergence is due to numerical or physical reasons.

Regime diagrams for several realistic AGCE configurations will be prepared. The effects of the radial variation of the dielectric body force and the centrifugal force will be included.

PUBLICATIONS SINCE JUNE 1983:

1. A Linear Analysis of the Transition Curve for the Baroclinic Annulus. T. L. Miller and R. L. Gall. Journal of the Atmospheric Sciences, 40 (1983), 2293-2303.

2. Finite-Difference Fluid Dynamics Computer Mathematical Models for the Design and Interpretation of Experiments for Space Flight. G. O. Roberts, W. W. Fowlis and T. L. Miller. NASA Technical Paper, April 1984.

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THEORETICAL AND EXPERIMENTAL STUDIES IN SUPPORT OF THE GEOPHYSICAL FLUID FLOW EXPERIMENT

April 13, 1984

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Meteorologists and astrophysicist interested in global planetary and solar circulations have long recognized the importance of rotation and stratification in constraining the character of these flows. In particular, the effect of latitude-dependent Coriolis force, the so-called beta-effect, is thought to play a crucial role in such phenomena as differential rotation on the Sun, cloud band orientation on Jupiter, and the generation of magnetic fields in thermally driven dynamos. Most theoretical works and all laboratory studies on these problems to date have treated the curvature effects only locally, and the laboratory efforts have only been able to study beta effects in layered quasi-geostrophic models. The continuous low-g environment of the orbiting space shuttle offers a unique setting for conducting geophysical fluid model experiments with a completely consistent representation of sphericity and the resultant radial gravity found on astro-geophysical objects. This is possible because in zero gravity one can construct an experiment that has its own radial buoyancy forces. The dielectric forces in a liquid, which are linearly dependent on fluid temperature, give rise to an effectively radial buoyancy force when a radial electrostatic field is applied. The Geophysical Fluid Flow Cell (GFFC) is an implementation of this idea in which fluid is contained between two rotating hemispheres that are differentially heated and stressed with a large a-c voltage. Our group has developed a facility to analyze the temeprature and velocity data that will come out of the GFFC experiment on spacelab III. In addition we have been working on many theoretical and laboratory problems which serve as models of expected GFFC motions, or bridges between the idealized situation of the GFFC and terrestrial, planetary, and solar circulations.

Research Accomplishments in the time period May 1983 - April 1984.

1) GFFC Data Analysis and Programming

Programming for digital acquisition of thermal maps and fluid velocities from the 16mm GFFC data films was completed. One remaining task is to attach our camera to the VAX-11 computer so that faster processing of each data frame can be effected.

On the basis of computer modeling and linear stability theory a set of scenarios (on-board programs that run the GFFC during the Spacelab III mission) were generated. The runs cover studies of basic electro-hydrodynamic instability, highly supercritical convection with isothermal boundaries, convection with imposed thermal forcing that has both radial and latitudinal structure, and some stably stratified runs to look at some very simple questions concerning large-scale thermohaline ocean circulations.

2) Studies of Compressible Convection.

To apply the Boussinesq results from GFFC to planetary and solar flows, some ideas about the effects of compressibility are needed. Hurlburt and Toomre have studied the effects of compressibility on thermal convection that is allowed to penetrate into stable surroundings, as is often typical of deep planetary or solar convection. Fully non-linear simulations of two-dimensional flows have been carried out on the Cyber 205 and on the VAX. These studies allow us to assess to what extent the GFFC experimental results without penetration may apply to more complicated circumstances within the Sun or the giant planets. For motions spanning several scale heights the cellular structure obtained in the compressible models are qualitatively similar to those predicted by our earlier incompressible studies. However, compressibility leads to distinctive asymmetries between the strengths of the upflow and downflow: pressure fluctuations cause stronger downward directed plumes. On encountering a stable layer these plumes can excite internal gravity waves and these in turn can couple back into the convecting layer and modulate its efficiency. The penetration effect is stronger in compressible models than Boussinesq ones because of the faster pressure-augmented plumes. The full numerical simulations of penetrative convection have been complemented by anelastic modal solutions by Toomre and co-workers.

3) Laboratory experiments on multiple equilibria and chaotic oscillators.

In 1979 Charney proposed that the atmosphere may contain multiple quasi-stable states. Since then Hart, Ghil and many others have looked for multi-equilibria in models of the Earth's atmosphere, of low Prandtl number Jovian convection, and of GFFC type convection. Hart and students have recently been studying a simple laboratory experiment that contains a convection front. This very simple experiment exhibits extremely complex dynamics including persistent states (hysteresis), frontal oscillations, intermittency in frontal formation, quasi-periodic oscillations and chaos. Some of the motions may be interpreted by simple convection loop theory. Others can be described by simple one-dimensional mappings (which unfortunately don't get at the underlying internal physics). As several of the GFFC experiments are designed to look for hysteresis and transition, these terrestrial laboratory studies are useful in building our intuition about how convective flows with competing instabilities work, and how to best analyse complex time series.

4) Transition to chaos in numerical models of double diffusive convection.

Toomre, Knobloch, Moore, and Weiss have performed some numerical calculations on 2-dimensional but many degree-of-freedom thermohaline convection. Remarkably the results show period doubling sequences (a la Feigenbaum) to chaos. The results are of interest to GFFC and to atmospheric dynamicists because they illustrate how period doubling can arise in relatively unconstrained fluid systems. Period doubling has been observed in laboratory models of baroclinic instability, and may occur in GFFC.

Plans for FY-85 (Including May 84 - Oct. 84)

1) Provide science support for the Spacelab III flight of GFFC.
2) Complete high-speed film-to-digital translator, and all data analysis programs.
3) Get linear convective instability and non-linear GFFC hydrodynamic codes up and running on the Cyber 205.

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4) Analyse the GFFC data film and compare results with theories of hydrodynamic stability, non-linear numerical models, and terrestrial laboratory experiments.
5) Continue our laboratory study of oscillations in convecting systems, as well as theoretical and numerical studies of diffusive and compressible convection.

List of publications and submissions supported wholly or partially by NASA contract NAS-8-31958

Hart, J.E., "Low Prandtl number convection between differentially heated end walls", Int. J. Heat and Mass Transport, 26, 1069-1074, 1983.

Hart, J.E., "A new analysis of the closed loop thermosyphon", Int. J. Heat and mass transfer", 27, 125-136, 1984.

Hart, J.E., "Alternative experiments using the Geophysical Fluid Flow Cell", NASA report CR-3766, 44pp, Jan. 1984.

Hurlburt, N.E., "Nonlinear compressible convection with penetration", Phd. thesis, Univ. Colorado, August, 1983.

Moore, D.R., J. Toomre, E. Knobloch and N.O. Weiss, "Period doubling and chaos in partial differential equations for thermosolutal convection", Nature, 103, 663-667, June 1983.

Massaguer, J., J. Latour, J. Toomre, and J-P Zahn, "Penetrative convection in a stratified atmosphere", Astronomy and Astrophysics, in press, 1984.

Hurlburt, N.E., J. Toomre, and J.M. Massaguer, "Two-dimensional compressible convection extending over multiple scale heights", Astrophys. J., in press, 1984.

Toomre, J., N.E. Hurlburt, and J.P. Massaguer, "Strong downward plumes resulting from compressibility in nonlinear convection and their coupling to gravity waves", Proc. Small-Scale Dynamical Processes in Quiet Stellar Atmospheres (ed. S. Keil), in press, 1984.

Knobloch E., D.R. Moore, J. Toomre, and N.O. Weiss, "Transitions to chaos in two-dimensional double-diffusive convection", J. Fluid Mech., to be submitted, 1984.

N84
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D4

Title: GFFC Experiment Progress

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The GFFC instrument was delivered to MSFC on August 4, 1983, and moved to the clean room, where the electronic connections were made and the instrument was powered up. Several problems were apparent upon attempting to execute a scenario for the first time. The control panel indicated an oil leak and switched to the standby mode. The UV cover was removed to inspect the leak detection system located on the oil bellows. Repeated measurements showed no oil leak was occurring, but the switch had been incorrectly positioned. The leak detection system was temporarily overridden in order to operate the instrument. After the UV cover was replaced, the instrument was charged with GN_2. By the next day most of it had leaked out. An inspection showed the leak was occurring through two electrical connectors. The connectors were repotted with a more appropriate compound.

In mid-August the GFFC was moved to the vibration facility where it was tested to flight levels on all three axes. This was the third vibration test. The first one several years ago was not successfully passed because a fracture in the data annotation housing occurred. The second test was successful. However, subsequent redesign invalidated this test, and a third vibration test was required. Afterward the instrument was returned to the clean room, and the turntable was removed in order to replace the silicon oil. The oil had inadequate photochromic dye dissolved in it, and the tracer dots had a short lifetime.

The Spacelab 3 crew received training on the operation of the GFFC instrument. The crew included payload specialists Mary Helen Johnston, Eugene Trinh, Lodewijk van den Berg, and Taylor Wang as well as mission specialists Norm Thagard and Don Lind, and pilot Fred Gregory. The training sessions were conducted by Fred Leslie and George Fichtl who briefed the crew on the science issues addressed by the experiment and gave a description of the hardware. The next day, the crew assembled in the clean room and operated the instrument. Training was also performed at KSC during the Level IV Mission Sequence Test. Additional training will be conducted with a GFFC simulator at MSFC's Payload Crew Training Complex.

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During October, the GFFC instrument successfully completed the out-gas test and acoustic test at MSFC, completing the instrument's flight qualification. The final ground science tests were conducted and the observations were reviewed with PI Prof. John Hart. The results of these tests were used to finalize the flight experiments to be conducted on-orbit. The scenarios were loaded into GFFC's memory, and some were run on the ground.

The GFFC is programmed for 59 experiments totaling more than 200 hours. Twenty experiments are related to the dynamics of the solar atmosphere. In general these are characterized by a rotating hot isothermal inner sphere and a relatively cool isothermal outer sphere. Fourteen experiments model the Jovian atmosphere having an unstable radial temperature gradient as well as a latitudinal temperature gradient. Stratified spin-up in a hemispherical shell comprises 10 experiments. This is a more basic experiment in fluid dynamics which examines the time-dependent motion of a fluid initially at rest reacting to the sudden start of rotation of its container. The process is further complicated by imposing a radially stable temperature gradient which suppresses radial motion. Nine general experiments examine the onset of convection for various Rayleigh and Taylor numbers. For a particular rotation rate and radial temperature gradient, the Rayleigh number will be gradually increased by increasing the effective gravity until the initiation of convection begins. Finally, six experiments are related to ocean circulation in that the fluid is stably-stratified in the radial directions, and the fluid motion is driven by a latitudinal temperature gradient.

Because of continued false-alarms by the oil leak detection system, the turntable of the GFFC was removed from the instrument housing and a new detection system was installed on the two accessible expansion bellows. The turntable was then reinstalled and functionally tested with no problems. A helium leak test was then performed to test the instrument's ability to retain gaseous nitrogen. The results of this test showed no significant leakage.

The GFFC Pre-Ship Review was held on January 5, 1984. Representatives from each lab presented materials summarizing their discipline's evaluation of the GFFC instrument. There were no open items for the experiment and the Review Board approved shipping the instrument to KSC. The GFFC was shipped the next day. A management decision was made not to perform any post-ship functional tests of the instrument.

Experiment emphasis now focuses on Spacelab integration and mission planning. A meeting of the Investigator's Working Group was held January 18-20. GFFC PI Dr. John Hart presented his plans for POCC (Payload Operations Control Center) operations and contingency procedures. Details of POCC training and familiarization were also discussed.

Dr. Fred Leslie travelled to KSC to support the GFFC functional test. The instrument is installed in Rack 11 and is mounted on the Spacelab floor along with the other experiments. The purpose of the test is to verify the interfaces between the Spacelab and the individual experiments. Some problems did arise. The turntable did not rotate initially as commanded. Troubleshooting traced the problem to some broken wires in a connector behind the electronics box. The cable was repaired, and the turntable performed as commanded. A second problem was the inability of the GFFC time code generator to remain synchronized with the Orbiter's Master Timing Unit although it would do so with an independent source. Rather than take the time and risk of removing the electronics box, it was decided to allow the GFFC to run on iternal timing and have a crewman note the Mission Elapsed Time of the start of each scenario.

Also during March, the Spacelab 3 Mission Sequence Test (MST) was completed. Dr. Leslie particiapted in the operation of the GFFC experiment during the appropriate timeline runs. Because of time signal synchronization problems, the GFFC operated on its internal clock alone, and crew procedures were revised to allow correlation between the internal clock and the actual Mission Elapsed Time Clock. Although no anomalies were noted using this method, a Field Engineering Change (FEC) was requested to insure that the GFFC would not pick up spurious noise. The FEC directed a 75 ohms resistor to be placed across the timing input line. This was accomplished before the end of the MST, and additional runs were made with the GFFC. One Interim Problem Report was filed against the experiment. This resulted when a measured sphere temperature was $5^{o}C$ lower than commanded. A similar problem occurred during testing at MSFC and was traced to inadequate grounding. All the grounding measurements were repeated at KSC and were within tolerance. Although this under-temperature condition could be a result of operating the experiment in a 1g environment, it is being investigated further.

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TITLE: Numerical Studies of Baroclinic Instability at Small Richardson Number

INVESTIGATOR: T. L. Miller
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SIGNIFICANT ACCOMPLISHMENTS FOR FY-84:

Although the large-scale Richardson number in the earth's atmosphere is generally large, on the mesoscale it may not be large. Hence, modes of instability (of a thermal wind) whose horizontal length is of mesoscale size may be important in organizing convection in certain situations. This has been discussed by numerous authors. Furthermore, baroclinic instability ot small Ri may be important in atmospheres of planets with interior heating combined with differential solar heating, and in particular, it must be considered a plausible explanation for the existence of the banded structure of Jupiter's and Saturn's cloud patterns.

Baroclinic instability at small Ri consists of competition between symmetric (Solberg) modes, zonal (Eady) modes, and possibly other modes whose orientation is neither symmetric nor zonal. There have heretofore been huge gaps in our knowledge of the physics of the first two modes except for special cases. There have been no investigations of the possibility of the third case, except for modes that are nearly symmetric. Finally, until our work there have been no investigations of the fully nonlinear development and equilibration of any of these modes.

In FY-84 three steps have been taken to correct these deficiencies in our knowledge. First, a study of the fully nonlinear development and energetics of the symmetric modes was completed. The nonlinear effects were quite strong and, in some senses, surprising. A journal article on this work has been accepted for publication. Secondly, a study of the dependency of the energetics of the symmetric modes upon the physical parameters has been completed. A paper describing this work is in the final edit stage and will soon be submitted for publication.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Thirdly, a linear study of the fully three-dimensional possibilities and of the small Ri Eady modes is underway. This includes an analysis of the energetics. The results thus far have shown many surprises and indicate that this system is a rich one indeed.

PLANS FOR FY-85:

The three-dimensional linear study will be completed, which will include an analysis of the energetics of the fastest growing modes. Work will begin on developing a fully nonlinear three-dimensional model.

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RECOMMENDATIONS FOR NEW RESEARCH:

Although the energetic analysis of the three-dimensional linear model will give some indication of the results of competition between various modes, a fully nonlinear three-dimensional model is required to determine the conditions under which (for example) the symmetric modes are dominant. The development of such a model should be supported. In conjunction with three-dimensional calculations to determine the preferred modes, the current two-dimensional model should be modified to include the zonal modes and used to investigate highly nonlinear flows, including transition to chaos.

Analysis of satellite and rawinsonde data of mesoscale systems should investigate possible effects of the symmetric modes in earth's troposphere. Analysis of meteorological data of planetary atmospheres (Jupiter and Saturn in particular) should include such investigations as well.

Laboratory investigations of small Ri baroclinic flows should be further pursued, using the apparatus currently operating. (See the report by Miller and Fowlis herein.)

PUBLICATIONS SINCE JUNE 1983:

T. L. Miller: The Structures and Energetics of Fully Nonlinear Symmetric Baroclinic Waves. J. Fluid Mech., in press (1984).

T. L. Miller: On the Energetics and Non-hydrostatic Aspects of Symmetric Baroclinic Instability. To be submitted to J. Atmos. Sci.

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N84 34835

TITLE: Laboratory Studies of Baroclinic Instability at Small Richardson Number

INVESTIGATORS: Timothy L. Miller
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SIGNIFICANT ACCOMPLISHMENTS IN FY-84:

As part of the scientific support studies program for the AGCE, laboratory studies of baroclinic and other convective instabilities have been performed for a thin layer of fluid between thermally conducting horizontal discs. A horizontal gradient is equally imposed upon the two (sapphire) discs, while a vertical temperature difference is also imposed. The apparatus is rotated with constant angular velocity. The Richardson number (Ri) is thereby controlled and can be made on the average arbitrarily small or large (although there can be a large spatial variation within the fluid volume).

There have been three types of modes identified. The first has a "spiral-arm" appearance, and exists for large enough horizontal thermal forcing, weak enough static stability, and large enough rotation. The source of this wave has been shown to be the Eady mode of instability by performing comparative experiments with the more traditional side-heated apparatus.

The second mode is due to convective instability in the thermal boundary layers which exist due to the thermally conducting horizontal boundaries. Without rotation, this appears as small-scale radially oriented rolls. For slow rotation, the rolls are skewed into a spiral. If the static stability is not large (and especially for negative static stability), these spirals persist for large enough rotation that the rolls appear to extend through the interior of the fluid. The appearance is almost symmetric for these higher rotation rates. Because this phenomenon does not occur for moderate-to-large horizontal heating, we do not believe this to be the symmetric (or almost symmetric) baroclinic instability (Solberg mode).

Finally, for strong enough negative static stability, thermal convection of the Benard type, but under the influence of rotation and horizontal heating, appears. We have not pursued a study of these modes in much detail.

Probably the most significant result of our research is that the symmetric (Solberg) mode was not found, even though it would be expected under certain experimental conditions according to infinite-plane theory.

PLANS FOR FY-85:

Laboratory studies will be coordinated with theoretical studies in an attempt to explain the lack of appearance thus far of the symmetric modes. (See the report by Miller, herein.) Some minor modifications to

the apparatus may be necessary to allow the simultaneous imposition of small Ri, large thermal Rossby number, and small Ekman number.

We shall begin studies with an apparatus with differentially rotating top and bottom boundaries. Continuous stratification will be provided by heating and cooling the top and bottom surfaces, respectively, analogous to the two-layer experiments of Hart.

RECOMMENDATIONS FOR FURTHER RESEARCH:

Detailed study of the second and third modes above would also have great relevance to GFFC. It would be advisable to perform such studies as scientific back-up for GFFC.

The Eady modes seen in this study have striking visual similarities to cold fronts in the troposphere. More detailed studies, mapping temperature and velocity fields, may prove to be very valuable aids to developing and testing theories of frontogenesis. Such studies are recommended.

PUBLICATIONS SINCE JUNE 1983:

T. L. Miller and W. W. Fowlis, "Baroclinic Instability at Small Richardson Number," Bull. APS, 28(9), 1369 (1983) (36th Meeting of the Division of Fluid Dynamics of the American Physical Society, Houston, Texas, November, 1983).

I.B. SATELLITE DOPPLER LIDAR

N84
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TITLE: Overview of Global Scale Research Doppler Lidar Activities

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Significant Accomplishments to Date in FY84:

1. Ground-based lidar experiments: The system sensitivity is being carefully calibrated and checked by means of ground-based tests. Sensitivity analysis is necessary to use the data in the determination of backscatter distribution.

2. Satellite lidar and backscatter: Analysis of ground-based data, system calibration, and planning for a global backscatter mission have been the primary activities in this area. The ground-based data and other analyses indicate that the system is not sensitive enough to measure the backscatter distribution adequately for a satellite lidar system assessment. The 84/85 data should provide a good start, however.

Plans for FY85:

We expect to have from the fall 1984 flights some quick-look publications on backscatter distribution before the start of the spring 1985 flights. Following the flights there will be data evaluation, quick-look science, and the starting of scientific analysis of the data.

The global backscatter mission will be planned. Cooperation between the various NASA centers will be arranged. We will investigate the possibility of cooperating with another center to get a more powerful laser to make backscatter measurements, upon completion of the 85 flight program.

Recommendations for new research:

Satellite Doppler lidar should be started on its way by making a global backscatter assessment, by design studies, and by performance studies.

SATELLITE DOPPLER LIDAR

2. Backscatter Data Analysis

a. G. Kent, IFAORS
   - o SAM/SAGE
   - o GAMETAG

b. W. Jones, MSFC
   - o focussed 10.6 lidar
   - o focussed 9.1 lidar
   - o pulsed lidar

c. J. Rothermel, USRA
   - o ground-based pulsed lidar

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SATELLITE DOPPLER LIDAR

1. Aerosol Physics/Backscatter

a. D. Bowdle, USRA
   - o cv990 FSSP data
   - o MSFC focused, pulsed lidars

b. G. Kent, IFAORS
   - o backscatter modelling

c. C. Bohren, Penn State
   - o backscatter modelling

Satellite Doppler Lidar

3. Satellite simulation/assessment

   a. D. Emmitt, Simpson Assoc.
      - o coherent mesoscale structures
      - o scanning, pulse requirements

   b. J. Bilbro, MSFC
      - o aircraft experiment

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Satellite Doppler Lidar

4. Backscatter Measurement

   a. W. Jones, MSFC
      - o focussed lidar

   b. J. Bilbro, MSFC
      - o pulsed lidar, calibration

   c. D. Fitzjarrald, et al., MSFC
      - o FY84/85 ADLS flights
      - o Proposal for FY85/86

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N84 34837

TITLE: ATMOSPHERIC BACKSCATTER RESEARCH

RESEARCH INVESTIGATORS INVOLVED:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

1. Refined scientific rationale for ongoing atmospheric backscatter research program based on "clean"/"dirty" airmass hypothesis. This research supports technology development studies for NASA's proposed space-based Doppler Lidar wind measurement system.

FOCUS OF CURRENT RESEARCH:

1. Analysis of MSFC airborne CO_2 backscatter measurements from previous field programs to evaluate spatial scales of backscatter variability and the correlation of backscatter and water vapor concentrations.

2. Analysis of backscatter measurements obtained by MSFC and other groups, as well as aerosol measurements obtained by other means, to evaluate the "clean"/"dirty" airmass hypothesis.

PLANS FOR FY-85

1. Analysis of MSFC airborne CO_2 backscatter measurements to be obtained during the FY 84/85 Doppler Lidar System field program.

2. Continuing analysis of backscatter measurements by other groups and aerosol measurements obtained by other means.

3. Continuing investigation of backscatter/water vapor correlations.

RECOMMENDATIONS FOR NEW RESEARCH:

1. Evaluate the potential of satellite imagery of atmospheric water vapor distributions to determine the distributions of aerosol backscatter.

PUBLICATIONS PREPARED SINCE JUNE 1983:

1. Bowdle, D. Aerosol effects on wind measurements from space: Rationale for an aerosol backscatter research program. In Preparation.

2. Oberbeck, V., and D. A. Bowdle. Atmospheric aerosol measurements in the central Pacific Ocean during the Global Tropopheric Experiment. In Preparation.

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TITLE: DEVELOPMENT OF A GLOBAL MODEL FOR ATMOSPHERIC BACKSCATTER AT CO_2 WAVELENGTHS

RESEARCH INVESTIGATORS: G. S. Kent - Principal Investigator
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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY 1984:

Work has commenced on three of the tasks included in the present study. These tasks are:

1. The investigation of the effect of aerosol microphysical processes on the back-scatter from an aerosol plume undergoing long-range atmospheric transport. A numerical model which examines the effects of coagulation and sedimentation on an aerosol size distribution is presently under development and the initial results for a single homogeneous layer have been obtained.

2. Use of the SAGE/SAM II data set to study the global variation of aerosol concentration and, hence, to predict the variation of β_{CO_2}. Computer programs have been written to determine the mean, median, and the probability distribution of the measured aerosol extinction as a function of altitude, latitude and geographical conditions. The first data sets analyzed in this way are presently under study.

3. Use of the GAMETAG data to study aerosol behavior over the U.S.A. and the Pacific Ocean. Further analysis of the GAMETAG data set, previously reported by Patterson et al., in 1980, has recently commenced.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The tasks described above will be completed. In addition, the available CO_2 lidar data set will be critically examined and a detailed intercomparison of the three data sets will be made with each other and with the results of the theoretical modeling. In this intercomparison an improved version of the aerosol models, published by Kent et al., in 198 will be employed.

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PLANS FOR FY 1985

To continue work on the modeling of aerosol back scatter. The emphasis of this work will be on the intercomparison of direct back scatter measurements at CO_2 wavelengths with predictions based on modeling and with measurements made at other wavelengths and by other techniques. The aim will be to identify weaknesses in the global models being presently developed and, hence, to identify those geographical areas and conditions where further direct measurement is needed and to assist in the development of suitable experimental programs.

RECOMMENDATIONS FOR NEW RESEARCH:

Simultaneous measurements of CO_2 lidar back scatter and other direct and indirect measurements of aerosol optical and mechanical properties (e.g., SAGE II). Close and detailed integration of these measurements and modeling. Measurements at CO_2 wavelengths other than 10.6 μm (e.g., in the 9.1 - 9.3 μm range) under different geographical and seasonal conditions. Theoretical and experimental investigation of non-aerosol scattering and extinction at CO_2 laser wavelengths, for example, that are due to sub-visible cirrus cloud.

PUBLICATIONS SINCE JUNE 1983:

None yet in this subject area.

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ATMOSPHERIC EFFECTS ON COHERENT LIDAR SYSTEMS

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Significant Accomplishments to Date in FY-84

Atmospheric effects on lidar systems at 10.6 μm wavelength comprise of molecular absorption, aerosol scattering and refractive turbulence effects. We have completed the work on the combined effects of beam truncation and atmospheric refractive turbulence on the system performance. This work was presented at the 2nd Topical Meeting on Coherent Lidar Technology at Aspen, Colorado and has been accepted for publication in Applied Optics.

Focus on Current Research

We have developed modeling of backscattering characteristics of atmospheric aerosols. The present effort is to complete this modeling and publish in open literature.

Plans for FY-85

Our aim for FY-85 is to make the AFGL computer program on atmospheric transmission operational on NASA-MSFC computer system and integrate it with simulation of satellite-borne lidar systems.

List of Publiations

"Refractive Turbulence Effects on Truncated Gaussian Lidar Systems", to appear in Applied Optics, 1984.

I.C. SATELLITE DATA ANALYSIS

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TITLE: Variational Objective Analyses for Cyclone Studies

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84

I. Theoretical development of the first analysis model (Model I).

The basic analysis equations, i.e., the two horizontal momentum equations, the hydrostatic equation, and the integrated continuity equation were derived for the nonlinear vertical coordinate, non-dimensionalized, and expressed in finite differences on a staggered grid. Special care was taken to transform the hydrostatic equation and the pressure gradient terms of the horizontal momentum equations to nearly eliminate truncation error over steeply sloping terrain. This formulation also eliminated explicit reference to orographically induced variations in the thermodynamic variables so that the variational adjustments are on the scale of the meteorological perturbations.

The analysis equations were subjected to the Euler-Lagrange operations as expressed for finite differences and an additional set of five partial differential equations was derived, bringing to nine the number of equations in Model I. Higher order terms, terms containing observed quantities, and terms containing none of the variables to be adjusted were grouped into forcing functions and the equations were solved for the zero-order terms. Zero-order variables were eliminated between these equations and there resulted two diagnostic equations which take the form of general linear second-order partial differential equations with non-constant coefficients. These will be solved with standard relaxation methods.

FOCUS OF CURRENT RESEARCH ACTIVITIES

The major current research activity is the translation of the Model I equations into computer code. This task has been broken into five program modules that are small enough to fit on the University of Illinois CYBER computer. The five program modules contain the following:

a. Terms and equations that need be calculated only once,

b. Equations that are calculated at one cycle below the highest cycle,

c. Equations that solve 3-dimensional, 2nd order partial differential equations with nonconstant coefficients,

d. Equations that are at the highest cycle level, and

e. Equations that monitor the convergence of the method.

In addition, an objective analysis of the 3-h AVE-SESAME I data set covering all of the United States east of 105 degrees west (except for New England) is underway. This analysis will serve as an independent data set to compare with the output from Model I. The analysis uses a modified Barnes method on a 40 x 25 x 10 grid with a horizontal grid spacing of 100 km and a vertical grid spacing of 100 mb above 700 mb. The analysis is done on the nonlinear sigma coordinate surfaces for three levels between the surface and 700 mb.

PLANS FOR FY-85

We plan to develop the theory and computer code a second variational objective analysis model (Model II), and to complete the performance analysis of Model I. Model II will contain the energy equation as an additional constraint.

PUBLICATIONS PREPARED SINCE JUNE 1983

Achtemeier, G. L.: An experiment in variational objective analysis for a limited area wind field. Accepted with revisions by J. Atmos. and Oceanic. Tech.

Achtemeier, G. L., Ochs, H. T., and S. Q. Kidder: A diagnostic numerical model for the application of satellite data for the study of global weather systems. To be presented at the Conference on Satellite Meteorology/Remote Sensing and Applications 25-29 June 1984.

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The Application of Satellite Data to Study the Effects of Latent Heat Release on Cyclones

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Significant Accomplishments FY-84:

Our research has concentrated more and more on understanding mesoscale convective processes and how they affect and interact with mid-latitude cyclones.

The diagnostic study of the March 1978 storm using conventional and satellite-cloud data has progressed to the point where

i. the ageostrophic and associated vertical motion field have been calculated using a highly accurate iterative method of solving the semi-geostrophic omega equation. A M.S student had attempted to solve the equation in a transformed geostrophic coordinate, but the inevitable smoothing errors involved with the transformation lead to highly suspect and inaccurate solutions. The new method shows how important ageostrophic vorticity and thermal advection is in the dynamics of the system.

ii. the tendencies for convective destabilization in the 850-750 mb layer due to (a) differential geostrophic and ageostrophic advection and (b) differential moist adiabatic ascent, have been found. We are attempting to explain the observed presence of embedded convection in the area of large-scale warm frontal ascent.

Satellite and conventional data reveal the presence of organized rainbands in convectively stable regions where there is no background shear for the bands to feed upon. We have developed a wave-CISK model (Xu and Clark, 1984) which shows that such bands can develop because of the released latent heating provided a non-equilibrium cloud model is used where the clouds, after being triggered by low-level moisture convergence associated with a traveling internal gravity wave, actively grow and decay in a life-cycle controled by (a) the supply of buoyant potential energy in the boundary layer and (b) small scale eddy dissipative processes. The wavelength amplitude and phase speed of the resulting traveling disturbance agrees quite well with field observations.

Dr. Qin Xu, now a post-doc at The University of Oklahoma, completed a dissertation entitled "Conditional Symmertric Instability and Mesoscale Rainbands". It is a comprehensive study of conditional symmetric instability (CSI) in a sheared, conditionally unstable environment.

For a uniform basic flow in which the wind shear, dry and moist stratifications are constant, linear solutions are found for different CSI modes, e.g., isolated, periodic, and hybrid modes. Inviscid growth rates, spatial structures including the formulae for the width and slope angle of moist updraft, and stability critria are found and discussed. When a bulk viscosity is accounted for, the most rapidly growing CSI circulations bear a close resemblance to some observed rainbands. The stability criterion of viscous CSI also shows a better comparison with observational data than inviscid CSI.

When generalized energy considerations are made, some of the above results are extended to linear CSI with a nonuniform basic state in which the stratification and shear of the basic flow are functions of space. The

generalized energetics are also studied for nonlinear inviscid SI. The results indicate: (a) the linear theory fails to predict the stability in certain cases where the basic state is transitional between stability and instability; (b) the initial growth of the SI perturbations can be fairly well approximated by linear theory, but the long time nonlinear evolutions will be bounded energetically if the SI region is finite. However, a further extension of the energetics to CSI shows that the nonlinear evolution of CSI circulation will energetically depnd much more on the precipitation in a complicated way.

By treating the latent heat as a source which is implicitly related to the motion field, the existence, uniqueness and stability of steady viscous CSI circulations are studied. Viscous CSI circulations are proved to be unique and asymptotically stable when the heat souces are weak and less sensitive to the motion perturbations. By considering the fact that moist updrafts are narrow and using eddy viscosity of $O(10^3\ m^2/s)$, the stability criterion suggests that some frontal rainbands were probably dominated by the CSI mechanism even in their mature quasi-steady stage.

Focus of Current Research:

The diagnositc semi-geostrophic model is now being used to evaluate the tendencies to make

$$S \equiv \frac{f + \delta}{f} - \frac{1}{Ri}$$

negative and thus, anticipate regions of potential CSI in the March, 1978 storm. Ri is the Richardson number, δ vorticity, and f the Coriolis parameter.

Plans for FY-85:

Once we have developed criteria to predict areas of potential convective activity in mid-latitude synoptic systems, we plan to include a convective parameterization scheme (already developed) in our diagnostic model and re-evaluate the ageostrophic motions and tendency field for the March, 1978 storm with large-scale as well as convective latent heating accounted for. In that way we can make a reliable assessment of latent heating effects on the system.

Publications:

Accepted for Publication

Xu, Qin and J.H.E. Clark, 1984: Wave CISK and Mesoscale Convective Systems, J. Atmos. Sci.

Submitted

Xu, Qin, 1984: The Basic Nature of Symmetrc Instabilty and its Similarity to Convective and Inertial Instability, Quart. J. Roy. Meteor. Soc.

Xu, Qin, 1984: Conditional Symmetric Instability and Mesoscale Instability, J. Atmos. Sci.

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The Use of Satellite Data in Understanding and Predicting Convective and Large-Scale Dynamical Processes

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Accomplishments in FY-84:

1. Observational Studies of the Index Oscillation

Mr. Robert Schlaak has completed his M.S. Thesis in which he has combined, in a unique way, conventional and NOAA-III and NOAA-IV Earth Radiation Budget (ERB) data to study the pronounced index oscillation of the 1974-75 winter. He has determined that the principal driving mechanism for the oscillation is barotropic wave-mean flow energy exchanges stimulated by the mean westerlies becoming periodically unstable. He has also determined that polar cap radiative processes are phased with the oscillation such as to reinforce it. Variations in mid and high latitutde cloud cover resulting from intrusions of warm air into high latitude regions modulate the net radiative cooling in such a way as to reinforce strong mid-latitude westerlies because of thermal wind balance and thus intensify the oscillation.

2. Theoretical Studies of the Index Cycle and Blocking Phenomena

A two-layer truncated baroclinic spectral model was developed to study the long-term evolution of disturbances to a baroclinically unstable mean flow. Topography and crudely-parameterized radiative processes were accounted

for. As a result of Mr. Schlaak's discovery of the underlying barotropic nature of the index oscillation as well as reviewers suggestions about the original manuscript, the model has been revised to allow for barotropic as well as baroclinic wave-mean flow interactions. The form-drag exerted by the topography on the barotropic part of the mean flow is larger than on the baroclinic part and thus we anticipate significant changes from the original calculations on the index oscillation when it is strongly modulated by topography.

3. Numerical Modeling of Index Cycle Variations

We believe that since the index oscillation accounts for a significant portion of atmospheric temporal variance, the long term predictability could be improved if reliable forecasts of the index oscillation were available. Two spectral models of the index oscillation, one barotropic and the other baroclinic, have been developed. The latter allows for moisture, radiation, land-sea temperature contrasts, and energy exchanges with the underlying surface. They are currently being tested for conservation of energy and vorticity.

4. Theoretical and Observational Studies of Cloud Streets

Two manuscripts, Shirer (1984) and Shirer et al. (1984), have been completed recently; these discuss results obtained from a three-dimensional truncated spectral model of moist convection in a shearing environment. In Shirer (1984), two possible cloud street modes arising from a combined Rayleigh/parallel instability were found to be possible--one having orientations for which the Fourier coefficient of the wind shear perpendicular to the roll was nearly zero and the other for which the Fourier coefficient of the shear parallel to the roll was nearly equal to that perpendicular to the roll. These two modes have different horizontal characteristic wavelengths

that vary with wind speed at the top of the domain, which is usually taken to be the base of the inversion. In Shirer et al. (1984), analysis of aircraft data taken during 4 cloud street cases from KonTur revealed that in each case the mode for which both shear coefficients were nearly equal corresponded to the observed one.

Work has begun on a three-dimensional spectral model able to represent the convective modes developing as a result of the inflection point instability. In addition, satellite pictures and relevant upper air data have been archived for 30 cloud street days during the 1983-84 winter season; these will be used to assess the results obtained from the above Rayleigh/parallel and inflection point instability models.

Plans for FY-85

1. Observational and Theoretical Studies of the Index Oscillation

We plan to concentrate on the analysis of our six-coefficient baroclinic-barotropic spectral model of the index oscillation. In addition, the blocking phenomenon will be analyzed by seeking low and high index equilibria and examining their stability. Further observational studies are planned which will concentrate on establishing the conditions leading to the establishment of atmospheric blocking patterns and their subsequent maintenance. A mix of conventional and satellite data is anticipated just as in our study of the index oscillation.

2. Modeling of the Index Cycle

It is proposed that the two spectral models be used to produce forecasts from observed fields. The desired prediction quantitiers are the index values, and the points of regime changes. The index values are, of course, calculated directly from the forecast height field. The regime changes may be

found by calculating the attractor associated with the forecast fields at certain points in the forecast cycle. If, for example, the associated attractor were calculated every 6 hours and changed after 36 hours, this would indicate a transition to another flow pattern. It is anticipated that several forecasts with slightly different initial conditions will be needed to establish the probability of a regime change. The form of the probability distribution for the change might take the form of a log-normal distribution. This sample stochastic approach also takes into account the possibility of no regime change -- something the single forecast cannot handle.

The calculation of the attractor restricts the number of spectral components to about 60 (or less) for practical reasons of computer time and core. Thus, the initial fields must be restricted to just the larger observed features. Since current satellite observing systems are able to resolve these scales, analyses derived solely from satellite observations should serve as satisfactory initial data.

3. Cloud Streets

The new inflection point instability model will be developed sufficiently that orientation angles and horizontal wavelengths can be predicted for the rolls and these results compared to both the KonTur data and the locally archived data. Development of approximate formulas relating for each possible mode the orientation angles to components of the mean wind shear is one goal of the analysis.

Preliminary work is planned on generalizing the present three-dimensional Rayleigh/parallel instability model to one able to represent the tranisitions from rolls having one wavelength to ones having other, larger ones. Such cell broadening is observed in laboratory models of Rayleigh-Benard convection and in satellite pictures of cloud streets over the ocean, and is modeled well

in a new simple spectral model of two-dimensional shallow convection given by Chang and Shirer (1984). The background wind field will likely play a crucial role in determining the details of this cell broadening, and will be an important factor in any usable boundary layer wind-measuring scheme.

Publications

Shirer, H.N. and R. Wells, 1983: Mathematical Sturcture of the Singularities at the Transitions Between Steady States in Hydrodynamic Systems. Lecture Note in Physics, 185, 276 pp.

In review or to appear:

Feldstein, S.B., J.H.E. Clark, 1984: The Hadley and Rossby Regimes on a Sphere, Monthly Weather Review.

Chang, H-R and NH.N Shirer, 1984: Transitions in Shallow Convection: An explanation for cell broadening. Journal of the Atmospheric Sciences.

Shirer, H.N., 1984: On Cloud Street Development in Three Dimensions: Parallel and Rayleight Instabilities. Contributions to Atmospheric Physics.

Shirer, H.N., B. Brummer and A. Grant, 1984: Cloud Streets During KonTur and the Parallel/Rayleigh Instability. Contributions to Atmospheric Physics.

Thesis completed:

Schlaak, R.A., 1984: An Observational Study of the Winter 1974/75 Index Oscillation with Conventional and Satellite ERB Data (in preparation for submission to Monthly Weather Review).

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TITLE: Determination of Rainfall and Condensational Heating in the South Pacific Convergence Zone During FGGE SOP-1

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS IN FY-84:

One of the primary objectives of this research, which began 15 October 1983, is to evaluate the role of cloud-related diabatic processesin maintaining the structure of the South Pacific Convergence Zone, SPCZ, (see Fig. 1). The method chosen to evaluate the condensational heating is a diagnostic cumulus mass flux technique which uses GOES digital IR data to characterize the cloud population. This method requires as input an estimate of time/area mean rainfall rate over the area in question. Since direct observation of rainfall in the South Pacific is not feasible, a technique using GOES IR data is being developed to estimate rainfall amounts for a 2.5 degree grid at 12h intervals. This resolution is consistent with the FGGE data set.

Estimating rainfall from space-based sensors involves numerous problems which are a function of temporal and spatial accuracy required. Although passive microwave techniques measure raindrop-sized hydrometeors, current observations are too infrequent (at best every 12h) to rely on this method alone. Instead we have opted for an IR method which, although providing only indirect rainfall estimates, can provide the near-continuous temporal coverage required. Since convective cloud clusters dominate the portion of the SPCZ near the Equator, observations approaching 1h frequency may be needed.

To date, IR schemes owe much of their success to their ability to identify raining vs. non-rainning areas (Lovejoy and Austin, 1979 MWR). Only limited skill has been demonstrated in providing rain rates on the scale of a few hours. The method developed in the present study incorporates not only IR temperature as a predictor, but expansion of cold cloud top area, IR cloud top morphology and environmental precipitable water. The cloud top expansion factor is based on a "floating" threshhold 10 C0 warmer than the time-mean minimum cloud top temperature within a 5.0° radius of the location in question. This feature allows the detection of of embedded convection in baroclinic waves, a situation that previous anvil expansion techniques are not designed to handle. Cloud top morphology in the form of the Laplacian of the temperature is used to identify regions of overshooting cells. Since the SPCZ extends from tropical to mid-latitude regions, the moisture available for precipitation production may vary considerably, even though the convective cloud structures may appear similar. To account for this, environmental precipitable water is used as an additional predictor.

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During the first three months of this project a survey of existing IR and visible rainfall estimation techniques was conducted and the current methodology adopted. It was decided to develop the regression model on a set of hourly raingauge data in coastal regions of the U.S. and island stations in the western Pacific. Selection of cases was limited to those in which rain was produced by maritime synoptic systems moving on-shore. Both middle latitude baroclinic waves and convective disturbances in tropical air masses were included. At this time approximately one-half of these cases have been processed to derive the required statistical parameters.

CURRENT RESEARCH FOCUS:

Present work involves completing the tabulation of the data base required to develop the regression model. In the remainder of FY-84 we will 1) complete the statistical data base, 2) test an independent data set of varying synoptic regimes to demonstrate the generality and transferability (from one climate to another), 3) apply the scheme to the SPCZ region and 4) use the cumulus mass flux method along with the estimated precipitation to determine condensational heating in the SPCZ.

PLANS FOR FY-85:

The tasks for FY-85 include:

1) Application of the analysis to the full extent of the South Pacific Ocean and diagnosis of the corresponding heating.

2) Comparison of the satellite-derived precipitation to that obtained through moisture budgets constructed with the FGGE data base.

3) Application of the heating estimates to diagnosing energy transformations and frontogenetical forcing involved in maintaining the SPCZ.

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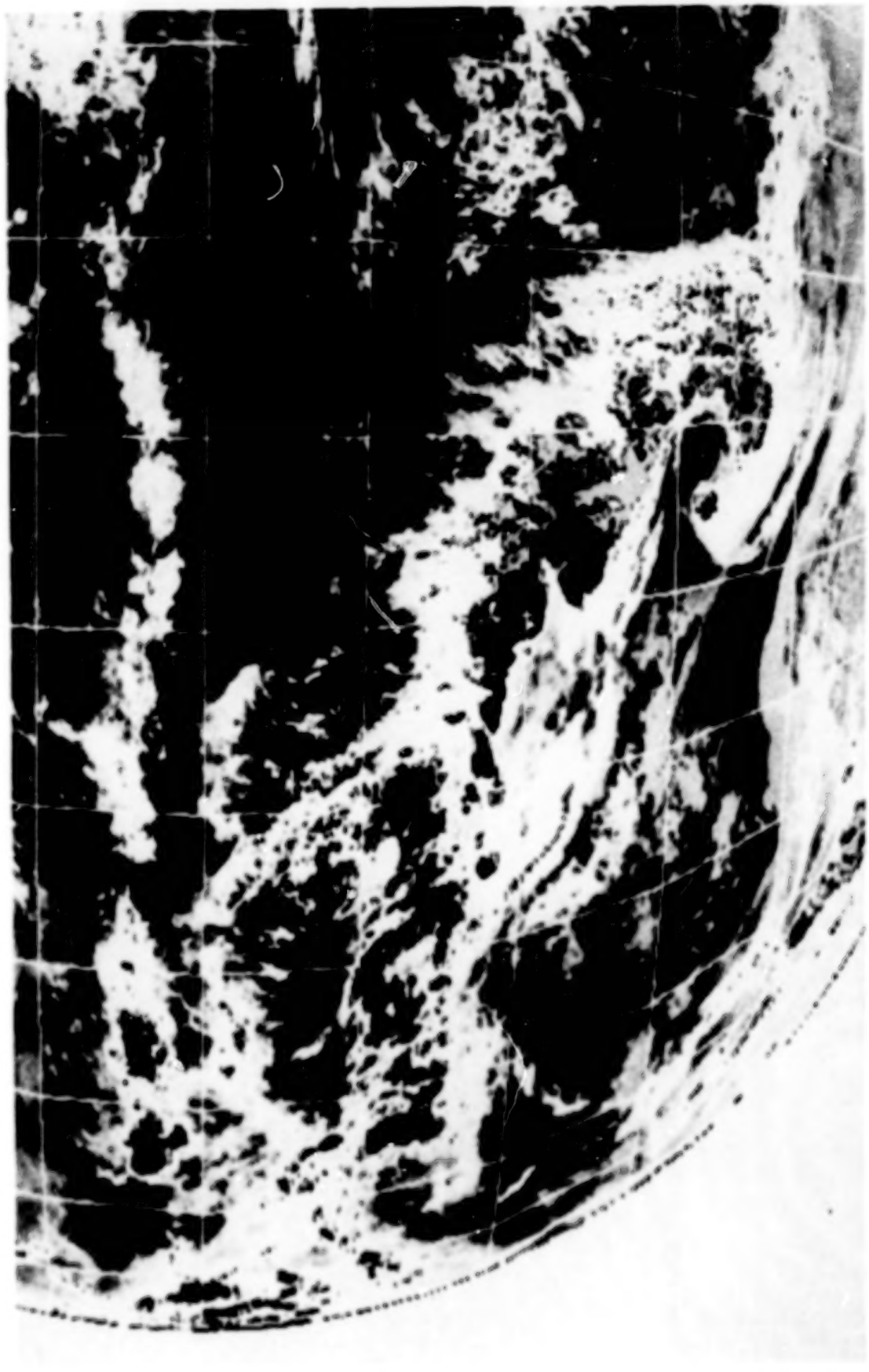

Figure 1. GOES West image at 1815Z 12 January 1979 showing the extent of the SPCZ cloud band. The image has been enhanced to emphasize the predominance of deep convection in the tropical portion and the existence of baroclinic waves at higher latitudes.

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N84 34844

TITLE: Use of Satellite Data in a Diagnostic Parameterization of Convective Heating

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SIGNIFICANT ACCOMPLISHMENTS IN FY-84:

1. Evaluation of AVE/SESAME-I Diagnosed Heating

Heating estimates derived from a diagnostic technique using observed rainfall and GOES IR digital imagery have been completed and evaluated for accuracy. Area-averaged values in the AVE/SESAME-I region are shown in Figure 1. A description of the diagnostic scheme is provided by Robertson (1983a). A sensitivity analysis was done to examine assumptions regarding shape of the normalized mass flux profile, cloud precipitation efficiency, and existence of convective-scale downdrafts. The results, which were derived using what are felt to be bounding limits of the assumptions, indicate that the heating estimates are reliable for use in diagnostic available potential energy (APE) budgets. Comparison to heating estimates derived as residuals in the thermodynamic equation show the level of maximum heating (near 300 mb) to be the same on a time-averaged basis.

2. Heating estimates have been used to study the response of the large-scale environment to the cumulus-scale thermodynamic forcing. An analysis of the thermally forced component of vertical motion through the omega equation

$$\nabla^2 \alpha \omega_h + f^2 \frac{\delta^2 \omega_h}{\delta p^2} = - \frac{R}{c_p p} \nabla^2 H ,$$

where ω_h is the thermally forced grid-scale vertical motion, α is the static stability and H is the diabatic heating rate, has shown that a significant fraction of the total grid-scale upward motion results from the heating provided by the condensation and vertical eddy heat transport in the convective cells.

3. The reformulated version of the available potential energy equation in pressure coordinates (Robertson, 1983) has been used to investigate the role of heating and local vertical overturning relative to boundary work and transport processes. The heating due to convection in the AVE/SESAME-I was

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found to have induced both thermally direct and indirect circulations, but contributed only minimally to changing the available potential energy of the SESAME region.

CURRENT FOCUS OF RESEARCH:

Application of the diagnostic parameterization and analysis of the available potential energy balance is being conducted on a second cyclone system, Mar. 6-7, 1982. This analysis will be compared to a numerical simulation of that case using the LAMPS (Limited Area Mesoscale Prediction System) recently implemented at MSFC.

PLANS FOR FY 84/85:

During the remaining months of this contract the energetics analysis will be completed on the Mar 6-7, 1982, case study.

RECOMMENDATIONS FOR FUTURE RESEARCH:

The methodology developed in this research provides a means for obtaining accurate vertical profiles of convective heating. The technique should be extended to utilize satellite-derived estimates of precipitation as a substitute for hourly surface observations. The utility of the revised APE equation should be investigated further with emphasis on the boundary work and flux terms. This work will be conducted under two new contracts utilizing the NMC FGGE IIIb data sets.

PUBLICATIONS AND PRESENTATIONS:

Robertson, F.R., 1983a: Cumulus-scale heating and its influence on mesodyanamics during AVE/SESAME I. Preprint 13th Conference on Severe Local Storms, Tulsa, OK, October 17-20, 1983, American Meteorological Society, Boston, MA, 02108, pp. 350-353.

Robertson, F.R., 1983b: Influence of convective heating on available potential energy during baroclinic development. 4th Extratropical Cyclone Workshop. Madison, WI, Nov. 1-2, 1983. (No preprint volume).

Robertson, F.R., 1984: Reference pressure change and the available potential energy of open systems. Conditionally accepted to Tellus.

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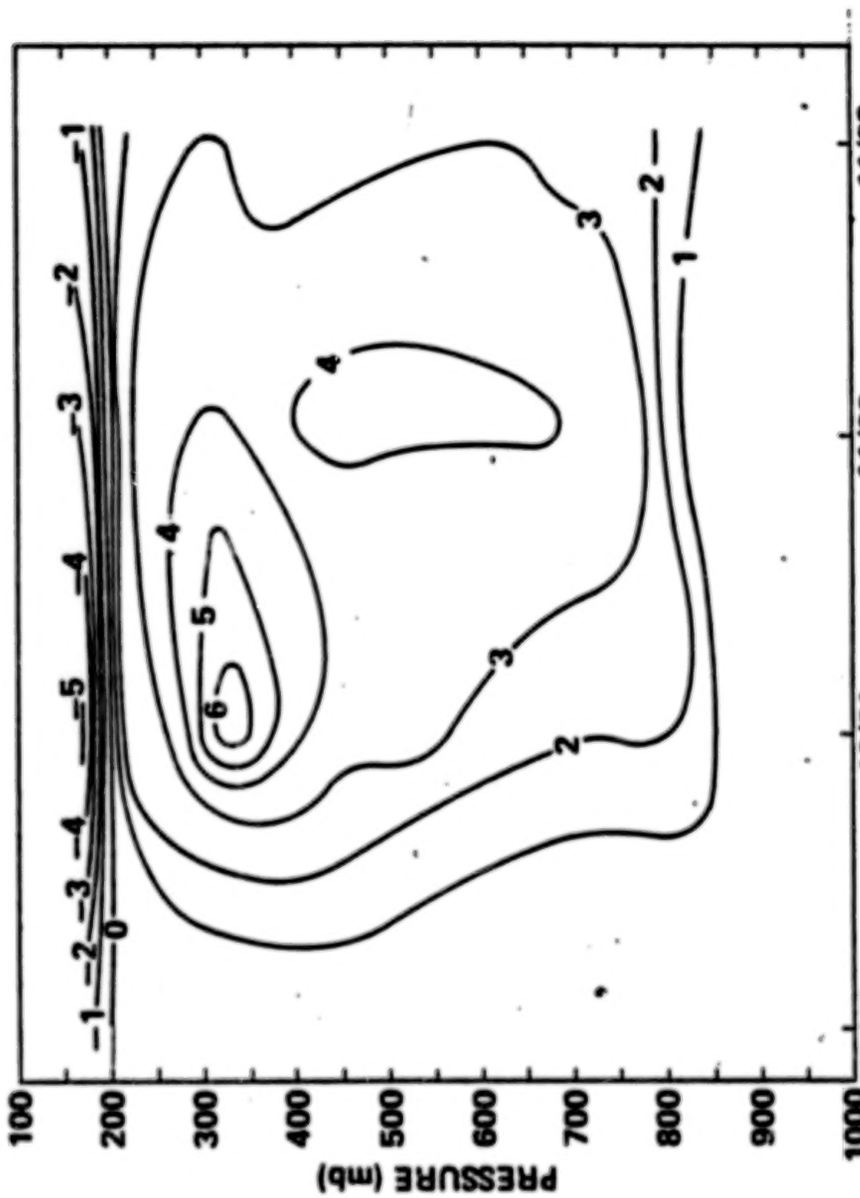

Figure 1. Convective diabatic heating rate in Deg/Day averaged over the SESAME network (1400 km on a side). Heating was diagnosed from a cumulus mass flux method using observed rainfall and cloud top heights determined from GOES data.

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Title: Observational and Theoretical Studies of the Evolving Structure of Baroclinic Waves

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Significant Accomplishments FY-84):

1) Dynamical processes involved in comma cloud formation, and passive tracer evolution, in a baroclinic wave. An analytical solution has been obtained demonstrating the complex nongeostrophic flow pattern involved in the redistribution of low level constituents in a finite amplitude baroclinic wave, and in the formation of the typical humidity and cloud distributions in such a wave. (Saltzman and Tang)

2) Observational and theoretical studies of blocking weather patterns in middle latitude flows. A series of studies have now been completed showing the differences in the energy and enstrophy cascades in blocking and nonblocking situations; it is established that pronounced upscale flow of both of these quantities, from intermediate to planetary scales, occurs during blocking episodes. The upscale flux of enstrophy, in particular, suggests that the persistence of blocking periods may be due to reduced dissipation of the large scale circulation and therefore entail some above normal predictability. The observational results also indicate that smaller scale transient eddies play an important, regime-dependent, role in interactions with atmospheric circulations on the scale of blocking.

In a theoretical study, some of the effects of these smaller scale, higher-frequency, eddies are modelled as both a stochastic white and red noise forcing of a bistable orographically induced stationary flow of the type studied by Charney and

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Devore. An important new time constant thus emerges, namely the 'exit time' for reversal between the two attractor domains of the steady flow representing blocking and normal states. These exit times were found to range widely as a function of the zonal forcing, and in the red noise case it is found that the bimodal nature of the barotropic model can be obscured depending on the prescribed variance of the perturbations and the model parameters. (Hansen)

3. Satellite-based measurements of the generation of available potential energy due to infrared radiative fluxes. Using global temperature data and satellite data it is estimated that the global pattern of IR causes destruction of both zonal and eddy available energy of magnitudes $G_z \approx -5.0 W\ m^{-2}$ and $G_E \approx -0.6\ W\ m^{-2}$, respectively. The destruction in the eddies is almost entirely due to the very long stationary disturbances of wavenumbers 1 and 2. (Hansen and Nagle)

Focus of Current Research and Plans for FY-85:

We are now well along in the development of a low-order non-linear forced dissipative baroclinic model that can replicate most of the classical results of baroclinic stability theory and open the door to a fuller study of the finite amplitude behavior of mid latitude disturbances and their evolutionary and statistical properties. Preliminary work is extremely promising for elucidating the influence of land-sea surface temperature contrasts (such as are found on the eastern coasts of the major continents) in the intensification of the waves. We hope to tie this theoretical study in with synoptic/satellite observational studies of cyclone intensification over oceanic regions.

Also underway is a large data-processing and analysis effort to examine an 8-year record of satellite measurements of the daily global distribution of outgoing infrared radiation for signatures of significant baroclinic wave activity leading to the formation of major blocking episodes. This work will form the basis for a thesis by R. Nagle, and already gives promise that further spinoff studies will follow.

Publications Prepared Since June 1983:

1) Saltzman, B. and C.-M. Tang, 1984: The effect of finite-amplitude baroclinic waves on passive, low-level, atmospheric constituents, with applications to cloud distribution and evolution. Tellus, (in press).

2) Tang, C.-M. and G. Fichtl, 1984: On non-quasigeostrophic effects in baroclinic waves with latent heat release. J. Atm. Sci. (in press).

3) Hansen, A.R. and A. Sutera, 1984: A comparison of the spectral energy and enstrophy budgets of blocking versus nonblocking periods. Tellus, 36A, 53-63.

4) Brown, P.S., A.R. Hansen, J.P. Pandolfo, and A. Sutera, 1984: Average characteristics of blocking and nonblocking events, (submitted).

5) Hansen, A.R. and A. Sutera, 1984: Observational aspects of the predictability of atmospheric blocking. Proc. Workshop on Predictability of Fluid Motions, AIP, New York, N.Y.

6) Benzi, R., A.R. Hansen, and A. Sutera, 1984: On stochastic perturbation of simple blocking models. Quart. J. Roy. Met. Soc., (in press).

7) Hansen, A.R. and R.L. Nagle, 1984: Estimates of the generation of available potential energy by infrared radiation. Mon. Weath. Rev., (in press).

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D17

TITLE: Utilization of Satellite Cloud Information to Diagnose the Energy State and Transformations in Extratropical Cyclones

PRINCIPAL INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS IN FY-84:

The work during FY-84 has focused on two aspects of the project.

1. A study of the contribution of latent heat release to the synoptic scale vertical motions in our Jan. 9-11, 1975 extratropical cyclone case study was completed. Results indicate that early cyclone development was dominated by dry dynamical forcing. However, as the cyclone matured, the influence of latent heating became more significant. This influence appeared to be of two types, (1) the "direct" impact of heating causing a lowering of surface pressures, and (2) an "indirect" role in which the heating altered thermal and vorticity gradients and lead to subsequent increases in dry dynamical forcing.

2. The kinetic energy budget completed by Patricia Dare in her master's degree thesis was extended to include an available potential energy budget. Focusing on the eddy component of the budgets, results indicate that kinetic energy increased throughout the cyclone's development, with the increase being most pronounced after the onset of significant latent heat release. Latent heating played a strong role not only in generating available potential energy, but also in forcing baroclinic release of potential energy.

CURRENT FOCUS OF RESEARCH:

Our present focus is on further diagnoses of the role of latent heating in the January 1975 cyclone's evolution. This is being accomplished by solving the quasi-geostrophic height tendency equation separately for the vorticity advection, differential temperature advection, and latent heat forcing terms. We are especially interested in the relative importance of the latent heat forcing. In addition, comparison with observed height tendencies will indicate the extent to which non-quasigeostrophic processes are important.

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PLANS FOR FY85:

As we enter the final year of the project, we plan to

(1) complete the height tendency diagnosis,

(2) complete the energy budget analyses, and

(3) replicate our latent heat modification experiment using SESAME I conventional data and cloud images.

PUBLICATIONS PREPARED SINCE JUNE 1983:

Lin, S.-J., 1983: Utilization of Satellite Cloud Information to Improve the Estimation of Latent Heat Release. M.S. thesis, Dept. of Geosciences, Purdue University, West Lafayette, IN 47907.

Dare, P.M., and P.J. Smith, 1984: A comparison of observed and model energy balance for an extratropical cyclone system. Mon. Wea. Rev., 112, accepted for publication.

Smith, P.J., P.M. Dare, and S.-J. Lin, 1984: The impact of latent heat release on synoptic-scale vertical motions and the development of an extratropical cyclone system. Submitted to Mon. Wea. Rev.

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Title: The Effects of Latent Heat Release on the Waves with Ekman Pumping

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Significant Accomplishments to Date in FY-84:

(1) Two-level model: A slab-symmetric two-level model has been investigated with the presence of the lower boundary friction. The profile of the vertical motion is sinusoidal in the moist region, but exponentially decaying in the dry regions. The mass continuity constraint and the condition of the continuity of the normal component of the velocity at the interface between the moist region and the dry region are satisfied. The results are similar to the results of Charney and Eliassen (1964) but without their extremely large growth rates for some medium horizontal scale. The most favorable horizontal scale is the cumulus scale, but the most favorable doubling time is order of a day, and there exists a cut-off of the domain size of the moist region beyond which the system is stable. When the internal friction is included, the growth rates are reduced for most of the unstable mode, but the stability cut-off disappears.

(2) Three-level model: The corresponding three-level model has been investigated. The instability is sensitive to the ratio of the heating parameter in the upper layer to that in the lower layer and the corresponding static stability ratio. For the model without internal friction, the stability diagram with the heating ratio versus the domain size of the moist region shows that as the static stability ratio increases, the unstable spectrum increases for a given heating ratio. Depending on the parameters, the most favorable horizontal scale can range from the cumulus scale to synoptic scale. With the internal friction included, the stability cut-off disappears and two unstable modes appear for large domain size for some parameters.

Focus of Current Research Activities:

Currently, the problem of the effects of the latent heat release on the waves with both upper and lower boundary frictional effects is investigated.

Plans for FY-85:

The influence of the vertical shear of the basic wind in these models will be investigated. These investigations will shed some light on the method of solution to the problem of including the effect of Ekman pumping on the moist baroclinic waves in the model of Tang and Fichtl (1983).

List of Publications Prepared since June 1983:

Tang, C-M., and Fichtl, G. H., 1984: Non-quasigeostrophic effects in baroclinic waves with latent heat release. J. Atmos. Sci. 41 (in press).

References:

Charney, J. G., and Eliassen, A., 1964: On the growth of the hurricane depression. J. Atmos. Sci. 21, 68-75.

Tang, C-M., and Fichtl, G. H., 1983: The role of latent heat release in baroclinic waves — without β-effect. J. Atmos. Sci. 40, 53-72.

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D19

Group-Kinetic Scaling as a Basis for Modeling Large Scale Turbulence

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I. NEW TRENDS IN TURBULENCE

In the NASA Workshop on Turbulence Modeling, at NASA Headquarters, Dec. 13-14, 1983, the trends in turbulence has been heavily debated. The recommendation was the need for new concepts and methods to develop a statistical theory of turbulence. The treatment should detach from the conventional concepts and should incorporate new insights from the modern statistical physics. Among them, the "catastrophe theory" was mentioned.

A nonlinear dynamical system can take the various forms of (i) algebric equations, (ii) ordinary differential equations, and (iii) partial differential equations. By the strong perturbations and the inherent nonlinearity, the system can become unstable, develop collective interactions, and reach a state of turbulence. The transition from the laminar motion to turbulence, and the characterization of those processes through which a nonlinear dynamical system undergoes before reaching turbulence are the subject matter of "chaos and universality". The interest on this topic is partially due to its easy availability to numerical computations, at least in one dimension and in the dynamical forms (i) and (ii). We must notice the important gap between the dynamical development of chaos and their statistical treatment. It is with the purpose of devising a mathematical tool for transforming the dynamical system into a statistical framework that we develop the group-kinetic method.

II. GROUP-KINETIC METHOD FOR THE TRANSFORMATION OF THE DYNAMICAL SYSTEM INTO A KINETIC SYSTEM AS THE BASIS FOR A STATISTICAL TREATMENT OF TURBULENCE

In our group method, the stochastic and nonlinear differential system, as governing the compressible turbulence and incompressible turbulence, undergoes three successive transformations. As the first step, we transform the differential system from the configurational space into the phase space. The resulting master equation becomes homogeneous, has lesser nonlinearity and emcompasses all the equations (for density, velocity and energy) of the dynamical system. Secondly, we note that the master equation and its Fourier decomposition contain too many minute details. For the statistical treatment a coarse-graining procedure by

group-scaling is necessary in analogy with the group-renormalization. To this end, we use the scaling operators A^o, A', A" to decompose a fluctuating quantity into the macro-group, the micro-group and the submicro-group of decreasing coherence, representative of the three transport processes of spectral evolution, eddy transport property and relaxation. By formulating the relaxation as a functional of the transport coefficient, we obtain a closure. The relaxation is investigated by a path-perturbation theory. This involves the evolution-operator and the derivation of the equation for the probability of retrograde transition. The kinetic equation thus obtained has an eddy collision coefficient in the form of an integral operator of memory. Thirdly, we transform the kinetic equation back into the configurational space by taking the moments. Hence we derive the equation of spectral flow for determining the spectral structure. The group-scaling has the important advantage of enabling the determination of the spectral function from the one-point distribution function alone, without the knowledge of the two-point distribution function as is required in the conventional methods of many-body statistical mechanics.

III. SPECTRAL STRUCTURE AS A BASIS FOR TURBULENCE MODELING

A. Shear turbulence and geostrophic turbulence

By the group-kinetic method, we find the direct and reverse cascades for the transfer across the spectrum. We derive the spectral distributions in inertia turbulence ($k^{-5/3}$ law), shear turbulence (k^{-1} law) and geostrophic turbulence. The geostrophic turbulence without driving force has a k^{-3} spectrum and the geostrophic turbulence with a random driving force has a k^{-4} spectrum.

B. Atmospheric boundary layer

For the convective turbulence in the stable atmospheric boundary layer, we find a spectral structure for the three subranges. The horizontal velocity components start with a buoyancy subrange of k^{-3} law, to be followed by a spectral gap, a shear subrange of k^{-1} law and an inertia subrange of $k^{-5/3}$ law at the tail of the spectrum. The vertical component has a depressed spectrum at small wavenumbers before it resumes the inertia tail.

C. Anisotropy

The self-consistent forces (pressure and buoyancy) act differently among the different components of the velocity spectral distribution. In the past their effects were

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assumed. Our group-kinetic method develops a homogeneous master equation that lumps these forces into the advection in the phase space, so that the path perturbations can be readily analyzed.

D. New concepts in the group-modeling of turbulence

For the prediction of profiles (mean wind velocity, temperature and humidity), a macroscopic version of our transport theory is needed. The closure of the transport hierarchy is obtained by a non-stationary theory of transport for the eddy stress and the pressure-strain correlation. The transport coefficients are integral operators of memory and are functionals of the spectral distributions, the mean flow parameters, and other dimensionless parameters, such as the Richardson number and the Rossby number. We summarize the following transport equations in the modeling: (i) the equation of spectral flow, (ii) the equations for the evolution of the transport coefficients, (iii) the transport equations of mean profiles, and (iv) the transport equations for the eddy stress and the pressure-strain correlation. The group-modeling is superior, because the conventional modelings have unknown scales and unknown length parametrization.

IV. ACCOMPLISHMENTS

Eight manuscripts have been completed by C. M. Tchen, and were compiled under two NASA Contractor Reports, entitled "Theory and Modeling of Atmospheric Turbulence".

Volume One contains the following manuscripts:

1. Kinetic basis of cascade transfer in turbulence 43 pages
2. Kinetic theory of turbulent transport with double memory-loss, 36 pages
3. Group-scaling theory for the enstrophy turbulence in two dimensions, 31 pages
4. Group-kinetic theory of turbulent collective collision, 44 pages.

Volume Two contains the following manuscripts:

1. Group-kinetic theory of two-dimensional geostrophic turbulence, 32 pages
2. Equivalent methods for describing the quasilinear turbulent trajectory, 29 pages

3. A new kinetic description for turbulent collisions, including mode-coupling, 29 pages

4. Spectral structure of turbulence in the stable atmospheric boundary layer, 14 pages.

V. PLANS FOR CONTINUING RESEARCH

Our group-kinetic method will be extended to the atmospheric processes with shear, stratification and Coriolis force. In particular, we investigate the following:

1. Eddy transport theory for the derivation of anisotropic transport properties
2. Kinetic theory of pressure-strain correlation
3. Spectral structure of anisotropic turbulence
4. Upper atmospheric boundary layer and inversion layer
5. Modeling of turbulence as based on the new concept of group-modeling, as outlined in Subsection IIID.

VI. RECOMMENDATIONS FOR NEW RESEARCH: MODULATIONAL INSTABILITY AND SOLITON TURBULENCE IN THE BAROCLINIC ATMOSPHERE

In 1926 Madelung observed a formal equivalence between a fluid system and the Schrödinger wave equation. He recommended this transformation for non-barotropic fluids preferably. The nonlinear Schrödinger equation is now of intense physical interest and has received a great attention for applications to plasma physics, astrophysics and ocean dynamics. Unfortunately the advantage of the correspondence between the concepts of fluid dynamics and those of wave mechanics has not been fully exploited in researches on the atmospheric wave processes.

The nonlinearity can be local, as in the cubic nonlinear Schrödinger equation. It is made non-local in the Zakharov equations. Zakharov added to the Schrödinger equation an acoustic equation for the non-local modulation. We recommend a modification of the Zakharov system by adding new scattering functions and new parameters representative of the baroclinic and rotational properties of the atmosphere. Not much progress has been reported on such modulational instabilities and soliton turbulence. The slow progress is due to the lack of a suitable mathematical tool. We are convinced that the group-kinetic method will help in overcoming this difficulty.

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D20

TITLE: Application of Satellite Data to Tropic/Subtropic Moisture Coupling

RESEARCH INVESTIGATORS: Aylmer H. Thompson
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Our objective is to utilize various satellite products from a number of satellites together with data observed from platforms available during the FGGE Special Observing Periods to diagnose synoptic scale events in data-void regions. Our focus is on episodes of northeastward traveling cloud bands which move out of the ITCZ over the eastern North Pacific Ocean. We call these events "moisture bursts".

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

1. Based on an objective definition of moisture bursts as observed in GOES West imagery, a climatology spanning two six-month cold seasons documented the mean characteristics of the bursts. About 10 events occur per month; their locations are distributed uniformly between the dateline and 110°W. A third six-month period, within the El Niño event of 1983-84, revealed a marked decrease and eastward displacement of burst occurrence, in spite of the intensification of convective activity in this region of the equatorial convergence.

2. Routine screening and validation of the FGGE data revealed the following shortcomings in spite of general high quality of the data set:

a) considerable missing data, even within the Special Observing Periods;

b) inconsistencies and errors within the coding and archiving of the FGGE data base, both at NCAR and at the World Data Center, which have not been encountered by other FGGE data users;

c) biases in the satellite-derived soundings with respect to co-located rawinsondes and dropsondes, which differ from those reported by other investigators, but are associated with geographic and synoptic variation.

d) time traces of co-located data which yield consistent but differing signals between satellite and in situ observations.

3. The primary advantages of satellite coverage are its temporal frequency (twice a day for polar orbiters) and its fine-scale horizontal resolution. We are developing procedures for taking advantage of these properties. These procedures include objective analysis of satellite channel radiance data, converted to brightness temperature; multiple regression and interpolation in space and time of VTPR channel data to a TIROS N framework to extend the time and space coverage; and eigenfunction decomposition in the horizontal, vertical and temporal dimensions, to summarize and synthesize the significant modes of variation.

4. Synoptic analysis has proceeded along three independent tracks:

a) Interpretation of synoptic fields analyzed by the European Center and NMC;

b) Preparation of additional synoptic products, based on the FGGE level II(b) observations, including satellite-derived wind fields, and detailed time-sections and cross-sections;

c) New synoptic analysis of satellite-observed brightness temperatures, calculated from individual channel data of the TIROS N instruments. Preliminary indications are that these data sources are of significance when used to investigate synoptic structure in data-void regions.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Current efforts are directed to the construction and statistical evaluation of the satellite channel-radiance fields. This information can then be incorporated into the synoptic interpretation of moisture bursts along with FGGE and NMC analyses.

PLANS FOR FY-85:

1. Relate the moisture burst climatology to typical upper level and lower level motion fields.

2. Perform a synoptic case study analysis of two moisture bursts using the fields of satellite data.

3. Perform balance studies of the moisture burst region to understand physical mechanisms and the relative utility of satellite observations.

4. Initiate a case study of a warm season moisture burst.

5. Initiate wind/cloud/moisture analysis in which predominant use is made of McIDAS.

RECOMMENDATIONS FOR NEW RESEARCH:

The sounding retrievals, moisture and temperature alike, have been tremendously useful, but they tend to reveal the satellite data in their poorest light--vertical resolution. We suggest continuing studies emphasizing the use of the moisture-observing capabilities of the satellites using both microwave and infrared channels. These studies should emphasize horizontal and temporal variations of satellite data and their relation to distributions of more conventional data. The horizontal resolution available from mapped single-channel data seems to provide an inexpensive yet valuable extension of the capability of currently-available information from satellite vehicles.

LIST OF PUBLICATIONS AND PRESENTATIONS:

McGuirk, J., A. Thompson, L. Anderson, Jr., and N. Smith, 1984: Reliability of circulation statistics over the tropical Pacific Ocean based on FGGE data. "Proceedings of the Seventh Annual Climate Diagnostics Workshop" Toronto, Canada, October 17-21, 1983. National Oceanic and Atmospheric Administration, Washington, D.C.

McGuirk,J., and A. Thompson, 1984: Transient tropical disturbances within the Pacific Hadley cell. Postprint Volume, 15th Tech. Conf. on Hurricanes and Tropical Meteorology, Miami, FL, Jan. 9-13,1984, Amer. Meteor. Soc., Boston, MA.

Thompson, A., J. McGuirk, L. Anderson, Jr., and N. Smith, 1984: Analysis of tropical synoptic disturbances using satellite-derived soundings and radiance data from selected channels. Preprint Vol.,Conference on Satellite Meteorology/Remote Sensing and Applications, Clearwater Beach, FL, June 25-29, 1984. Amer. Meteor. Soc., Boston, MA.

N84
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D21

N84 34850

TITLE: Dynamics and Energetics of the South Pacific Convergence Zone During FGGE SOP-1

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE:

The contract is a new one and began on 15 October 1983. Our major objectives are to: (1) diagnose the physical processes responsible for the maintenance of the South Pacific Convergence Zone (SPCZ) and (2) examine the role of the SPCZ in the large-scale circulation patterns of the Southern Hemisphere. To accomplish these objectives, we initiated a series of tasks which should take about three years to complete.

Our first task was to acquire the necessary data. This was recently completed with the gracious help of Dr. John Ward of the National Meteorological Center (NMC). We now have a set of grid-point analysis at increments of 2.5° lat/lon for the globe for the period 10-27 January 1979. The set contains twice daily values (0000 and 1200 GMT) of horizontal wind components, geopotential height, temperature and relative humidity at all mandatory pressure levels from 1000 - 100 mb. It is based on Level III-b analyses originally produced by the European Centre for Medium-range Weather Forecasts (ECMWF). A detailed description of this data set appears in Vincent (1982). We also have acquired, at essentially no cost, weekly averages of sea surface temperatures from NESDIS/NOAA, twice daily values of Level III-b mean sea level pressure from ECMWF, 6-hourly surface charts with station data from NMC, 6-hourly GOES-W enhanced IR satellite imagery and twice daily charts of outgoing longwave radiative energy from NESDIS. Finally, we are currently in the process of supplementing our data set with various satellite products derived from the McIDAS system and computing facility at MSFC.

Our second task, which is currently underway, is to investigate cyclone development in the SPCZ, since it appears to play an important role in some of the Zone's physical processes (e.g., condensational heating and precipitation). Vincent (1984) is in the process of revising a manuscript which describes the life cycles of two SPCZ-cyclones. A Ph.D. student, Ms. Deirdre Kann, has begun a thorough investigation of these two cyclones, including a diagnosis of their energy budgets and the extent to which baroclinic processes are important. In this study, we plan to apply a cumulus parameterization scheme, developed by Dr. Robertson, which estimates vertical distributions of different forcing functions on cumulus heating. We also are using satellite-derived products, such as IR satellite imagery and cloud-top temperatures, to deduce cloud amounts and types.

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A third task, also presently in progress, is a study by another Ph.D. student, Huo-Jin Huang, to compute Southern Hemisphere energy budgets for the tropics (0 - 30 S) and middle latitudes (30 - 60 S), as well as the South Pacific portion of the tropics. His study includes a diagnosis of energy conversions and contents in: (1) zonal and eddy form based on compilations derived both in spatial domain and mixed space-time domain; and (2) wave number domain. Mr. Huang also has been examining variables related to daily variations of convective cloud systems (SPCZ and others) in the Southern Hemisphere.

Papers, which have been published to date, that relate to the above-named tasks are Vincent (1982), Huang and Vincent (1983), Robertson (1983), Vincent and Huang (1983), Vincent et al. (1983), Huang (1984) and Huang and Vincent (1984). The research for the last paper, plus the manuscript by Vincent (1984) were conducted primarily under this contract.

FOCUS OF CURRENT RESEARCH:

Our current research involves the work of Ms. Kann, Mr. Huang and Dr. Vincent noted above. In this context, Dr. Vincent and two of his graduate students, Ms. Kann and Mr. Bernie Miller spent the week of 4 March 1984 at Huntsville, AL discussing research with Dr. Robertson and using the McIDAS system and MSFC computing facility to conduct their research. While there, they briefed Dr. George Fichtl, Branch Chief for global-scale processes, on their research progress. Our ongoing research also includes the work done by Dr. Robertson on modifying his cumulus parameterization scheme for application to the SPCZ. An important aspect of his research is to obtain quantitative estimates of satellite-derived IR precipitation rates. Details of his work are discussed elsewhere in this report.

PLANS FOR FY-85:

In the coming year we plan to focus our research efforts in four areas: (1) completion of SPCZ and Southern Hemispheric energetics work begun by Mr. Huang; (2) completion of the cyclone cases investigation begun by Dr. Vincent and Ms. Kann; (3) extension of Dr. Robertson's cumulus parameterization scheme and work on satellite-derived precipitation estimates to regions beyond the SPCZ; and (4) initiation of work by Mr. Bernie Miller to use satellite-derived sea surface temperatures, together with our ECMWF data set, to compute moisture budgets for the SPCZ and Southern Hemisphere. The latter task will provide us with another estimate of precipitation to compare with Dr. Robertson's results.

Since this contract was only recently initiated, it is not feasible at this time to suggest recommendations for new research.

PUBLICATIONS:

Vincent, D.G., 1982: Circulation features over the South Pacific during 10-18 January. Mon. Wea. Rev., 110, 981-993.

* Huang, H-J. and D.G. Vincent, 1983: Major changes in circulation features over the South Pacific during FGGE, 10-27 January 1979. Mon. Wea. Rev., 111, 1611-1618.

* Robertson, F.R., 1983: Cumulus-scale heating and its influence on meso-a dynamics during AVE/SESAME I. Preprint, 13th Conference on Severe Local Storms, Tulsa, OK, October 17-20, 1983, American Meteorological Society, Boston, MA, 02108, 350-353.

* Vincent, D.G. and H-J. Huang, 1983: The role of stationary waves in maintaining the South Pacific Convergence Zone. Preprint, International Conference on the Stationary Wave Component of the Atmosphere, Paris, France, 29 August - 2 September 1983, 4 pp.

* Vincent, D.G., H-J. Huang and R.A. Fulton, 1983: Diagnostic analysis of the South Pacific Convergence Zone during FGGE SOP-1, 10-27 January 1979. Preprint, First Conference on Southern Hemisphere Meteorology, Sao José dos Campos, Brazil, 31 July - 6 August 1983, American Meteorological Society, Boston, MA, 02108, 4pp.

* Huang, H-J., 1984: Daily variations of convective cloud systems in the tropics during FGGE SOP-1, 10-27 January 1979. Postprint, 15th Technical Conference on Hurricanes and Tropical Meteorology, Miami, FL, January 9-13, 1984, American Meteorological Society, Boston, MA, 02108, 4 pp. (in press).

* Huang, H-J. and D.G. Vincent, 1984: Potential to kinetic energy conversion in wave number domain for the Southern Hemisphere. Preprint, 10th Conference on Weather Forecasting and Analysis, Clearwater, FL, June 25-28, 1984, American Meteorological Society, Boston, MA, 02108, 6 pp. (in press).

* Published since June 1983

II. MESOSCALE PROCESSES RESEARCH

NASA'S
MESOSCALE ATMOSPHERIC PROCESSES
RESEARCH PROGRAM

- **WHAT IT IS**
- **WHERE WE HAVE BEEN**
- **WHAT WE ARE NOW**
- **WHERE WE ARE GOING**

Dr. James C. Dodge, Program Manager
Atmospheric Dynamics & Radiation Branch
Earth Science & Applications Division
Office of Space Science & Applications
NASA Headquarters

THE PROGRAM

- GOAL ORIENTED BASIC RESEARCH

- PEER REVIEWED PROPOSALS

- NATIONAL IN SCOPE

- INTERAGENCY COOPERATION

- INTERNATIONAL COOPERATION

- REIMBURSABLE TECHNOLOGY TRANSFER

— WHERE WE HAVE BEEN —

- 100'S OF PROFESSIONAL PAPERS AND REPORTS
- CENTRALIZED STORM INFORMATION SYSTEM AT NSSFC
- PARTICIPATION IN SESAME, CCOPE, AVE/VAS
- REMOTE SENSING CAMPAIGNS FROM ALL HIGH-ALT. AIRCRAFT
- PROOF THAT WIND CAN BE MAPPED FROM AIRCRAFT WITH DOPPLER LIDAR
- DEMONSTRATED FEASIBILITY OF DAYLIGHT LIGHTNING OBS.FROM GEO
- EVALUATED METEOROLOGICAL UTILITY OF VAS
- DEMONSTRATED FREEZE FORECAST SYSTEM FOR FLORIDA CITRUS
- DEVELOPED AND EVALUATED A REAL-TIME MESO. NUMERICAL MODEL
- DEVELOPED AGRO-CLIMATIC/ENVIRON. MON. SYS. FOR BANGLADESH
- CREATED STATE-OF-THE-ART METEOROLOGICAL IMAGE ANALYSIS/ DISPLAYS
- OBSERVED LARGE SCALE LIGHTNING PROPAGATION FROM SPACE SHUTTLE

CURRENT THRUSTS

- AIRBORNE DOPPLER LIDAR WIND MAPPING
- ER-2 AND U-2 OBS. OF STORM TOPS AND LIGHTNING
- NUMEROUS MODELING AND ANALYSIS PROJECTS
- PLANNING FOR PARTICIPATION IN GALE (FIRE), SPACE AND MIST

NEAR-TERM EMPHASES

- USE OF TOTAL O_3 AS AN INDICATOR OF STRAT.-TROP. DYNAMICS
- INTERFEROMETRIC AIRBORNE TEMPERATURE SOUNDER
- HIGH-RESOLUTION WATER VAPOR/SURFACE CHARACTERISTICS MAPPING
- INVESTIGATION OF STORM-ENVIRONMENT FEEDBACK MECH.
- "MESOSCALE BOUNDARY" INTERACTIONS

FRONTIER RESEARCH AREAS

- LAND/OCEAN SURFACE FLUX EFFECTS ON DEVELOPMENT
- STORM FEEDBACK EFFECTS ON MESOSCALE CIRCULATIONS
- STRATOSPHERIC-TROPOSPHERIC DYNAMICS NEAR TROPOPAUSE
- WATER VAPOR DISTRIBUTION EFFECTS ON STORM DEVEL./ EVOLUTION
- MESOSCALE CIRRUS CLOUD DISTRIBUTION EFFECTS
- STORM ENSEMBLE INTERACTIONS
- THUNDERSTORM DYNAMICS/LIGHTNING GENERATION RELATIONSHIPS
- MESOSCALE CLOUD HEIGHT FIELD EVOLUTION/IMPLICATIONS
- MESOSCALE PRECIPITATION ESTIMATION/MODELING
- EAST COAST CYCLOGENESIS
- MESOSCALE BOUNDARY LAYER EVOLUTION

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II.A. ATMOSPHERIC ELECTRICITY

ATMOSPHERIC ELECTRICITY SESSION
PROGRAM OVERVIEW

The Atmospheric Electricity Program is directed toward developing techniques to observe and study lightning phenomena from the perspective of space. This pursuit requires both the development of state-of-the-art remote sensing and data processing techniques and basic research that seeks to improve our understanding of relationships between storm systems and lightning activity. Major areas include:

(1) Lightning mapper development studies.
(2) U-2 based lightning research.
(3) Ground based severe storm research.
(4) Long range remote sensing of storms.

Each phase of the program is complementary to another and they tend to be tightly bound. U-2 measurements are required for lightning mapper development while ground data are needed to interpret the U-2 measurements. All available data sets are utilized during detailed case studies. Future basic research studies will not only include the present observational program, but will be expanded to include additional modeling and theoretical studies.

PRINCIPLE SCIENTIFIC REQUIREMENTS

- CONTINUOUS COVERAGE
- LARGE AREA COVERAGE
- STORM SYSTEM RESOLUTION
- HIGH DETECTION EFFICIENCY
- HIGH TEMPORAL RESOLUTION
- FLASH INTENSITY INDICATION

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LIGHTNING MAPPER SENSOR CAPABILITIES

- AROUND THE CLOCK OPERATION
- NEAR FULL DISK COVERAGE
- 10 km X 10 km SPATIAL RESOLUTION
- DETECT 90 PERCENT OF ALL LIGHTNINGS WITHIN FIELD OF VIEW
  10 PERCENT FALSE ALARM RATE
- STROKE/FLASH DISCRIMINATION
  REAL TIME DATA DISSEMINATION
- FLASH RADIANCE MEASUREMENT

SCIENTIFIC OPPORTUNITIES POSSIBLE WITH MAPPER IN GEOSTATIONARY ORBIT

- MAGNETOSPHERIC AND IONOSPHERIC RESEARCH
  - RELATIONSHIP BETWEEN LIGHTNING AND WHISTLERS
  - VLF–ELF ELECTROMAGNETIC NOISE
  - VLF WAVES
  - SCHUMANN RESONANCES
- EARTH'S ELECTRIC CIRCUIT
  - FAIR WEATHER ELECTRICITY
  - IONOSPHERIC CURRENTS
  - ATMOSPHERIC CURRENTS
- ATMOSPHERIC CHEMISTRY
  - NITROGEN FIXATION
  - OZONE REACTIONS
  - RADICAL AND OXIDANT FORMATION
  - HCN FORMATION
  - STRATOSPHERIC CHEMISTRY
- STORM PHYSICS
  - LIGHTNING ACTIVITY/STORM INTENSITY
  - OCEAN LAND LIGHTNING RATIO
  - HURRICANE ELECTRIFICATION
  - LIGHTNING/TORNADIC ACTIVITY
  - INITIAL ELECTRIFICATION
  - SYMPATHETIC LIGHTNING
  - WARM CLOUD LIGHTNING
- SOLAR–TROPOSPHERIC EFFECTS
  - SOLAR VARIABILITY/LIGHTNING RATES
  - ELECTRICAL CONNECTION

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LIGHTNING MAPPER SYSTEM DEVELOPMENT STATUS

- MAJOR SYSTEM REQUIREMENT–DETECTION OF LIGHTNING DURING DAYTIME. MUST IMPLEMENT MULTIPLE FILTERING TECHNIQUES THAT MAXIMIZE LIGHTNING SIGNAL RELATIVE TO BACKGROUND "NOISE".
- FOCAL PLANE DESIGN IN THE MAIN EFFORT. WHERE THE FINAL BACKGROUND FILTERING WILL BE IMPLEMENTED. THIS IS THE CRITICAL DESIGN PARAMETER FOR THE LIGHTNING MAPPER.
- FOCAL PLANE PROCESSOR MUST .
  - REMOVE THE BACKGROUND FROM THE LIGHTNING. (BACKGROUND SIGNAL MAY BE UP TO 50 TIMES BRIGHTER THAN THE LIGHTNING SIGNAL AT THE FOCAL PLANE.)
  - REDUCE THE DATA RATE FROM ON THE ORDER OF 10^{10} BITS PER SEC TO LESS THAN 10^{5} BITS PER SEC.
- STATUS
  - U–2 MEASUREMENTS INDICATE THAT THE DAYTIME MEASUREMENTS ARE NOT AS DIFFICULT AS ORIGINALLY ESTIMATED.
  - RECENT STUDIES BY HUGHES AND TRW HAVE CONFIRMED THE FEASIBILITY FOR THE DETECTION AND LOCATION OF LIGHTNING FROM GEOSTATIONARY ORBIT.
  - MAIN SYSTEM COMPONENTS WILL INCLUDE

    OPTICS SYSTEM – CONVENTIONAL DESIGN

    NARROW BAND FILTER – INTERFERENCE

    FOCAL PLAN ARRAY – CUSTOM DEVELOPMENT REQUIRED BUT WITHIN STATE–OF–THE–ART.

    BACKGROUND REMOVAL – IMPLEMENTED OFF THE FOCAL PLANE USING ANALOG TECHNIQUES.

    FORMATTER AND ENCODER – CONVENTIONAL DESIGN

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TITLE: SEVERE STORM ELECTRICITY

RESEARCH INVESTIGATORS:

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Dr. W. David Rust, NOAA/NSSL,
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SIGNIFICANT ACCOMPLISHMENTS FY 83:

We have made significant progress in both our field work and analyses since the last program review. Some of these are:

1. Successful ground truth support of U-2 overflights. Data have been reduced for 4 June 1984 and some of the results have been integrated into some of MSFC's efforts.

2. We continue to find that "staccato" lightning (multiply branched, single stroke flash with no continuing current) is prevalent within the rainfree region around the main storm updraft and believe this to be important, i.e., staccato flashes might be an important indicator of severe storm electrification.

3. Results from our analysis of data from two stations appear to indicate that we can estimate charge center heights from a combination of intercept data with data from the fixed laboratory at NSSL.

4. We have provided an excellent data base for determining the sight errors and efficiency of NSSL's LLP system.

5. We successfully launched Dr. Marshall's (UM) radio sonde and electric field meter from a mobile launch vehicle.

6. We continue to observe cloud structures, observable in a low radar reflectivity region and on a scale smaller than is currently resolved by radar, which appear to be related to electrical activity.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

We are currently preparing the storm electricity van for the Spring 84 research program. We expect to be in Oklahoma from 12 May-10 June to support U-2 overflights. We are continuing our data reduction and analysis. Much of our effort this year was concentrated on 4 June 1984, but we continue our studies of a series of mesocyclones on 17 May 1981.

We shall continue to improve our abilities to launch and track balloon borne instruments from a mobile lab.

PLANS FOR FY 85:

Our goal remains unchanged; we shall continue our efforts to expand our knowledge of how storm electricity is related to cloud and precipitation structure, dynamics, and thermodynamics.

Each year our electricity measurements from the mobile laboratory become better integrated into the total electricity and dynamics effort. We plan to continue this trend. Storm intercept continues to play a supportive role in the overall severe storms electricity research and our data plays an important part of many analyses.

PUBLICATIONS SINCE JUNE 1983:

The following papers were presented at the 13th Conference on Severe Local Storms.

1. "Location of Lightning Charge Center near Mesocyclones" by Steven D. Horsburgh, Roy T. Arnold. D. G. MacGorman, and W. David Rust.

2. "Positive Cloud-to-Ground Flashes in Severe Convective Storms" by W. David Rust, D. G. MacGorman, and Roy T. Arnold.

The following papers will be presented at the International Conference on Atmospheric Electricity at Albany in June.

1. "Simultaneous Observations of Cloud-to-Ground Lightning above and Below Cloud Tops," S. J. Goodman, H. J. Christian, W. D. Rust, D. R. MacGorman, and R. T. Arnold.

2. "Some Characteristics of Lightning in Severe Storms on the Great Plains of the United States," D. R. MacGorman, W. L. Taylor, W. D. Rust, and R. T. Arnold.

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TITLE: Maxwell Currents Beneath Thunderstorms

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Significant Accomplishments:

We have completed analyses of single station measurements of the Maxwell current density (Jm) made under Florida thunderstorms during the summer of 1981. The results of these analyses indicate that:

(1) Jm is usually dominated by the displacement current component when the electric field is close to zero;

(2) Jm is steady with time in the intervals between lightning flashes;

(3) Jm is not altered significantly by lightning; and

(4) the average value of Jm changes slowly and over time scales that are comparable to those required for storm development.

We have also derived maps of the surface Maxwell current density for a number of the Florida TRIP (76-78) storms using field mill data to estimate Jm from the displacement current density. Our studies show that these maps provide a good indication of the location and relative intensity of the storm current generators, and area-integrations of the current contours provide estimates of the total storm currents. During a storm, the current density patterns develop and change shape slowly with time, so that current maps can be used to monitor the electrical development of a storm in space and time.

We conclude from our studies that Jm is an electrical quantity that may be coupled directly to the meteorological structure of the storm and/or the storm dynamics.

Focus of Current Research Activities:

Attempts are being made to infer the location, magnitude, and geometry of the current sources aloft from surface current density estimates by applying a least-squares minimization procedure to simple models.

Plans for FY-85:

The University of Arizona will make improved measurements of Jm this summer in Florida to investigate further the behavior of Jm under thunderstorms.

Recommendations for New Research:

Experiments to measure the Maxwell currents over the tops of thunderclouds are presently being considered for future U-2 programs. From these studies, we may be able to establish relationships between total storm current and cloud top optical emissions which later can be used to infer from optical measurements alone the electrical activity and energy output of a storm and its contribution to the atmospheric electric circuit and the charge budget of the earth. The results of these studies will be valuable in interpreting Lightning Mapper Sensor data.

Publications:

Blakeslee, R. J. and E. P. Krider, The horizontal variations of the Maxwell current density under Florida thunderstorms, EOS (Trans. Am. Geophys. Un.),64,1983 (abstract only).

Blakeslee, R. J. and E. P. Krider, The electric currents under thunderstorms at the NASA Kennedy Space Center, Preprints, VII International Conference on Atmospheric Electricity, Albany, New York, June 4-8, 1984.

N84
34853

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N84 34853 D24

Title: **Nighttime Observations of Thunderstorm Electrical Activity from a High Altitude Airplane**

Research Investigators: Dr. Marx Brook
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Dr. Bernard Vonnegut
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205-453-5218

Significant Accomplishments:

Observations of nocturnal thunderstorms made from above by a NASA U-2 airplane disclose features of cloud structure and lightning that are not generally visible from the ground. Most, if not all, lightning activity seems to be associated with clouds having strongly convective cauliflower tops. When the lightning occurs deep within the cloud, it can be seen that the folds and creases of the cauliflower top are not superficial surface characteristics, but extend deep into the cloud.

In both of the storms that were studied lightning channels are visible in the clear air above the cloud in 5-10% of the lightning events. This finding shows that substances known to be produced by thunderstorm electrical discharges, such as NO_x and O_3 can be introduced directly into the stratosphere. More detailed measurements will be required to determine whether or not the quantities introduced are of importance.

The cause and nature of the discharges above the cloud are not clear. Possibly they may be produced by accumulations of space charge in the clear air above the cloud. Alternatively the discharges may arise solely because of the intense electric fields produced by charges within the cloud. In the latter case the ions introduced by these discharges will have the effect of increasing the electrical conductivity of the air above the cloud and will increase the conduction current that flows from the cloud to the electrosphere.

Lightning spectra observed from above thunderstorms do not appear to differ significantly from similar observations of lightning that have been made from the ground beneath the cloud. More quantitative data at higher resolution may eventually show significant spectral differences between cloud-to-ground and intracloud strokes.

Our findings show that electric field-change data taken with an electric field-change meter mounted in an airplane provide data on lightning discharges from above that are quite similar to those obtained from the ground in the past. The transients produced by the photocell optical system correlate well with those provided by the E field-change meter. It appears that even though E field-change measurements cannot be made from a satellite, the optical signals from dart leaders, from return-strokes, and from continuing currents are recognizable, and in some instances, can be used to provide detailed information on the fine structure of lightning. In particular, they can be used to distinguish between cloud-to-ground and intracloud flashes.

We have emphasized the "optical alone" aspect of sensing lightning discharges from above clouds because of the interest in satellite measurements, especially from geosynchronous altitude. Clearly, optical measurements from a single platform are uniquely suited to provide the space and time resolution necessary to view an earth hemisphere on which hundreds of thunderstorms may be active simultaneously. Additional scientific objectives have been discussed in Davis, et al. (1983), and an update of the presently used instrumentation package, with some preliminary statistics on optical pulse frequency, is given in Christian, et al. (1983).

Focus of Current Research Activities:

Photographs of nocturnal thunderstorms showing lightning channels and cloud structure taken in recent flights will be compared with that which has already been analyzed to determine the extent of the variability of these phenomena.

Plans for FY-85:

FY-85 will be devoted to further analysis of data that has been obtained and preparation of supplemental U-2 instrumentation for flights in 1986.

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D25

TITLE: Lightning Mapper Development - Status and Requirements

RESEARCH INVESTIGATOR: Hugh J. Christian
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SIGNIFICANT ACCOMPLISHMENTS:

The feasibility for the detection and location of lightning on a continuous basis using a sensor in geostationary orbit has been established. Based on extensive quantitative U-2 based measurements of the optical characteristics of lightning and the capabilities of modern solid state mosaic focal plane arrays, calculations indicate that the question is not whether it is possible to detect daytime lightning from geostationary orbit but rather how high a detection efficiency can be acheived.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The present focus of the lightning mapper development effort is toward strengthening the scientific justification for placing a lightning sensor in geostationary orbit. Those research areas that are expected to lead to a stronger in-depth understanding of the role of lightning activity in storm processes or address the interpretation and application of lightning mapper type data sets are being emphasized. This work includes U-2 and ground based lightning research as well as modeling and theoretical studies.

PLANS FOR FY-85:

(1) Continue scientific research focused on providing the quantitative, detail rationale necessary to provide for a lightning mapper new start.

(2) Perform mosiac array brass board tests and evaluations in order to determine the actual performance levels achievable with both analog and digital real time processors and to evaluate alternate background removal algorithims.

LIST OF PUBLICATIONS:

"Observations of Optical Lightning Emissions From Above Thunderstorms Using A-2 Aircraft", with R. L. Frost, P. H. Gillaspy, S. J. Goodman, O. H. Vaughan Jr., M. Brook, R. Orville and B. Vonnegut, Bulletin of American Meteorological Society, 64, (1983), 120-123.

"Some Scientific Objectives of a Satllite-Borne Lightning Mapper", with M. H. Davis, M. Brook, B. G. Heikes, R. Orville, C. G. Park, R. G. Roble, and B. Vonnegut, Bulletin of American Meteorological Society, 64, (1983), 114-119.

"Simultaneous Observations of Lightning Above and Below Thunderstorms", with S. J. Goodman, EOS, 64 (1983), 660.

"A Technique for the Detection of Lightning From Gostationary Orbit", with W. W. Vaughan and J. C. Dodge, EOS, 64 (1983), 660.

"Lightning and Related Phenomena in Thunderstorms and Squall Lines", with R. D. Rust, W. L. Taylor, D. R. MacGorman, E. Brandes, V. Magus, R. T. Arnold, T. Marshall and S. J. Goodman.

"Optical Characteristics of Lightning as Measured from above Cloud Tops", with R. L. Frost and S. J. Goodman, Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., 4.

"The Detection and Location of Lightning from Space", with W. W. Vaughan, and J. C. Dodge, Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., 4.

"Lightning Observations From Above Clouds", to be presented at the VII International Conf. on Atmospheric Electricity and submitted for Special Edition Vol. ofd the JGR.

"Techniques for the Detection and Location of Lightning From Geostationary Orbit", with W. W. Vaughan and J. C. Dodge, Preprints, Conf. on Satellite Meteorology/Remote Sensing Applications, Am. Meteor. Soc.

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D26

Title: Solar Influence on Terrestrial Weather and Global Lightning Patterns via Cosmic Ray Modulations

Research Investigator: Dr. John T. A. Ely
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Significant Accomplishments to Date in FY-84:

1. We have obtained additional cosmic ray neutron monitor data needed for use in three of our analyses: (1) solar activity influence on ionization of the upper troposphere and tropopause; (2) solar activity influence on Canadian high stratus in winter; and (3) the S3-4 satellite study of IMF/GMF magnetic coupling effects. Because of the new data acquisitions, we have trained two new data processing analysts. These tasks are now in process.

2. A general theory paper has been completed (see below) on the magnetic coupling model of solar activity influence on atmospheric processes. The magnetic coupling model is used to explain a number of seemingly diverse studies with emphasis on those concerning lightning incidence.

Focus of Current Research Activities and Plans for FY-85:

1. Continue the analyses, now in progress, of solar activity influence on atmospheric processes, especially those affecting high clouds and global lightning patterns.

2. Finish other theory papers, several of which appear in condensed form in the general paper just completed (see below).

Recommendations for New Research

1. Continue and expand measurement of upper troposphere ionization by three means: (1) cosmic ray neutron monitors on the earth's surface; (2) long duration super pressure balloons, both circumpolar and equatorial; and (3) low altitude polar orbit satellite cosmic ray surveys (i.e. the S3-4 SPEX experiment).

List of Publications Prepared since June 1983

1. "Cosmic Rays, Solar Activity, Magnetic Coupling and Lightning Incidence", to appear in the Proceedings of the International Conference on Lightning and Static Electricity, June 26-28, 1984, Orlando, Florida.

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N84 34856 D27

TITLE: LIGHTNING OBSERVATIONS ABOVE AND BELOW CLOUDS

Research Investigator: Steven J. Goodman
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Significant Accomplishments to Date in FY-84:

1) A study of the quantitative optical characteristics of cloud-to-ground (CG) and intracloud (IC) lightning above clouds is nearing completion. A data base of a number of pulse parameters such as energy, rise times, pulse widths and pulse intervals has been compiled and categorized for first return strokes, subsequent strokes, the intracloud part of CG flashes and IC flashes. Major conclusions from this study are 1) single stroke CG's are more readily distinguishable from IC flashes than multiple stroke CG's; 2) there is no significant difference between the energy of first and subsequent return stroke pulses; and 3) the pulse rise times and pulse widths are time broadened.

2) An initial study of lightning activity in a mesoscale convective weather system (MCS) has been undertaken. CG flash rates average almost 50 per minute for 7 hours. U-2 observations of lightning above storms embedded within the MCS show that IC lightning activity can be much greater than CG activity at certain times in the MCS lifecycle.

Focus of Current Research Activities:

The quantitative analysis of the optical pulse characteristics of lightning measured from the U-2 is being completed with a few pulse discrimination techniques for distinguishing CG from IC flashes being tested. More emphasis will be given on studies relating the lightning observations to storm structure and evolution.

Plans for FY-84:

Doppler radar and lightning ground strike density data sets will be compared to evaluate the ground strike density technique for storm cell characterizations. Current research activities using U-2 observations will continue.

Recommendations for New Research:

Determine if there are more single stroke CG's during the early part of the storm life cycle since these flashes appear to be readily detectable from above clouds. This will require a thorough literature search and examination of ΔE data from NSSL.

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List of Publications Prepared Since June 1983:

Rust, W. David, W.L. Taylor, D.R. MacGorman, R.T. Arnold, S.J. Goodman, and V. Mazur, 1983: "Storm Electricity Research in Oklahoma: An Overview," Preprints, 8th International Aerospace and Ground Conference on Lightning and Static Electricty, DOT/FAA/CT-83/25, pp. 1.1 - 8.

Goodman, Steven J., 1983: "Lightning Activity Associated with Severe Storms Embedded Within a Mesoscale Convective Storm Complex, Preprints, 13th Conf. on Severe Local Storms, Am. Meteor. Soc., pp. 29 - 32.

Goodman, Steven J., and H.J. Christian, 1983: "Simultaneous Observations of Lightning from Above and Below Thunderstorms," EOS, Vol. 64, No. 45, p. 660.

Rust, W.D., W.L. Taylor, D.R. MacGorman, E. Brandes, V. Mazur, R.T. Arnold T. Marshall, H. Christian and S.J. Goodman, 1984: " Lightning and Related Phenomena in Thunderstorms and Squall Lines, AIAA 22nd Aerospace Sciences Meeting, Reno, Nevada, 9 pp.

Goodman, S.J., H.J. Christian, W.D. Rust, D.R. MacGorman, and R.T. Arnold, 1984: "Simultaneous Observations of Cloud-to-Ground Lightning Above and Below Cloud Tops," Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., 7 pp.

Christian, H.J., R.L. Frost and S.J. Goodman, 1984: "The Optical Characteristics of Lightning as Measured from Above Cloud Tops," Preprints, VII International Conf. on Atmospheric Electricity, Am. Meteor. Soc., 4 pp.

Johnson, R.L. and S.J. Goodman, 1984: "Atmospheric Electrical Activity Associated With Hurricane Alicia," Preprints, VII International Conf. on Atmospheric Electricity, AM. Meteor. Soc., 4 pp.

N84
34857

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N84 34857 D28

TITLE: STORM SEVERITY DETECTION (RF)

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

To provide lightning location data occurring in association with continental thunderstorms and hurricanes, a second phase linear interferometer was deployed at Marshall Space Flight Center during March 1982. Using time correlated directional data obtained at the site in San Antonio, Texas and at MSFC, Alabama, electrical emissions originating from tropical storms in the Gulf of Mexico were monitored. This period of time did not provide as much data as had been expected. In particular, the time span between hurricane ALLEN (10 August 1980) and hurricane ALICIA (18 August 1983) represents the longest period in this century that the United States has gone without hurricane landfall. Both systems were active and were acquiring data, however, during the landfall period of hurricane ALICIA.

In the time period between 2300 GMT, 17 August 1983 and 1000 GMT, 18 August 1983, there resulted 73,000 estimates of location of electrical events in the Gulf of Mexico and Texas coastal region. These data have been processed to remove bearing ambiguities, and this analysis has removed approximately 60,000 spurious points. The resulting data set of location estimates is 14,000.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The collection of atmospheric electrical events is being correlated with the McIDAS data base at Marshall Space Flight Center, and with the radar summary data provided by the Hurricane Research Division using the NWS radar facility at Galveston, Texas.

PLANS FOR FY-85:

The location data acquired from hurricane ALICIA will be analyzed to produce a case study of the electrical activity as a function of storm severity and evolution. The large data base resource of electrical

and meteorological information will permit analysis in a composite sense to study basic physical processes of cloud electrification in hurricane ALICIA.

Refurbishment of the phase linear interferometer at MSFC is currently under way and will be completed before the 1984 hurricane season.

RECOMMENDATIONS FOR NEW RESEARCH:

Since the data disk buffers of both phase linear interferometers are of limited extent, the storage capacity can be expanded using a communication link between the two sites. This capability would also provide real time location analysis.

Due to daytime ionospheric absorption effects, it has proven necessary to operate at higher frequencies during daylight hours. The mechanism to coordinate this activity at both sites must be introduced.

LIST OF PUBLICATIONS PREPARED SINCE JUNE 1983:

Johnson, R. L. and S. J. Goodman, "Atmospheric Electrical Activity Associated with Hurricane ALICIA," VIIth International Conference of Atmospheric Electricity, Albany, NY, June 1984.

Johnson, R. L. and S. J. Goodman, "Measurement of Atmospheric RF Emissions from Tropical Cyclones," Abstract submitted for presentation at XXIst General Assembly of URSI, Florence, Italy, August-September 1984.

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34858

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N84 34858

D29

Title: The Optical Characteristics of Lightning

Investigator: E. Philip Krider
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Accomplishments to Date:

Optical signals (0.4 to 1.1μm) radiated by Florida lightning were recorded in correlation with wideband electric field signatures. The amplitudes and time-behavior of the early portion of the signals produced by return strokes indicate that this lightning process produces a space- and time-averaged peak radiance on the order of 4 to 13 x 10^5 watts per meter of channel.

Integrals of the Poynting vector of the electromagnetic (EM) field radiated by return strokes indicate that the peak EM power is on the order of 3 to 20 x 10^9 watts at the source. When this peak EM power is produced, the optical power is at least 2 orders of magnitude smaller, hence an upper limit to the radiative efficiency of the channel at this time is about 1%. From these measurements we also infer that at the time of the initial current peak, (1) the total voltage drop on the high-current portion of a return stroke must be at least 2 to 7 x 10^5V in first strokes and 2 to 4 x 10^5V in subsequent strokes, (2) the total resistance of the high-current channel must be at least 6 to 20 Ω in subsequent strokes, and (3) the energy that is required to form the propagating tip of the channel must be at least 10^2 to 10^3J/m.

Recent analyses of the light signals radiated by dart leaders indicate that a small but important fraction of these signals exhibit an unusually large peak output per unit length of channel, i.e. values that are comparable to or even exceed those of the subsequent return stroke.

Data derived from a large network of electric field mills and alightning locating system have been used to obtain the average diurnal variation of summer lightning in Florida. When the statistics of lightning are compared with the statistics of thunder on the same days, good agreement is found between the start times and the times of peak activity; however, the thunder stop times tend to lag the lightning by 1 to 2 hours. The diurnal variations over the Atlantic Ocean and the Gulf of Mexico are substantially less than over land. Over land, the diurnal variation is such that a DMSP satellite can, at best, detect 0.0007, 0.0004, and 0.0028 of the actual discharges at midnight, dawn, and dusk, respectively. If there were no diurnal variation this satellite would detect about 0.0014 of the actual number.

Current and Future Activities:

We have established a cooperative experiment on the radiative properties of long sparks in air with members of the High Voltage Institute at the University of Uppsala, Sweden. We plan to analyze optical data that are produced by long sparks (whose power and energy inputs are known) to determine better the power and energy balance of these processes and ultimately lightning.

Efforts are also being made to understand how the rates of lightning activity in various thunderstorms relates to the total Maxwell current that is being generated by these storms. The results are expected to make an important contribution to our understanding of the thunderstorm as a source in the global circuit.

Publications:

"The Optical Power Radiated by Lightning Return Strokes" J. Geophys. Res., 88, 8621-8622, 1983 (with C. Guo).

"The Peak Electromagnetic Power Radiated by Lightning Return Strokes," J. Geophys. Res., 88, 8471-8474, 1983 (with C. Guo).

"Anomalous Light Output from Lightning Dart Leaders" Trans. Am. Geophys. Union, 64, 662, 1983 (Abstract with C. Guo).

"Average Diurnal Variation of Summer Lightning Over the Florida Peninsula" to be pub. Mon. Wea. Rev., 1984, (with L. M. Maier and M. W. Maier).

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N84 34859 D30

Title: Remote Observations of Severe Storms

Research Investigator: Richard E. Orville
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Significant Accomplishments:

A lightning detection system has been operating along the East Coast since August 1982. I believe that this will prove to be one source of ground truth for lightning flashes detected from above clouds. In addition, the first absolute spectral irradiance measurements over a wide wavelength range have been reported. A paper reporting on the observations of lightning from a U2 aircraft is now under review.

Focus of Current Research Activities:

We will be analyzing the data from the East Coast Lightning Detection Network, continuing our spectral analyses, and cooperating on further U2 aircraft measurements.

Plans for FY-85: Continue the current research activities.

Recommendation for New Research: Stengthen the ground based and U2 observations of lightning research to determine the need for continuous observations of lightning from space.

List of Publications since June 1983:

"Observations of Optical Lightning Emissions from above Thunderstorms Using A-2 Aircraft", with H.J. Christian, R.L. Frost, P.H. Gillaspy, S.J. Goodman, O.H. Vaughan Jr., M. Brook, and B. Vonnegut, **Bulletin of American Meteorological Society, 64,** (1983), 120-123.

"Some Scientific Objectives of a Satellite-Borne Lightning Mapper", with M.H. Davis, M. Brook, H. Christian, B. G. Heikes, C.G. Park, R.G. Roble, and B. Vonnegut, **Bulletin of American Meteorological Society, 64,** (1983), 114-119.

"Simultaneous Observations of Lightning Ground Strokes and Radar Reflectivity Patterns", with S.G. Geotis, **21st Conference on Radar Meteorology, September 19-23, 1983,** Edmonton, Alta., Canada, (1983), 57-58.

"An East Coast Lightning Detection Network", with R.W. Henderson and L.F. Bosart **Bulletin of American Meteorological Society,64**, (1983), 1029 - 1037.

"Correlated Observation of Three Triggered Lightning Flashes", with V.P. Idone, P. Hubert, L. Barret and A. Eybert-Berard, **Journal of Geophysical Research**, (1984), **89**, 1385-1394.

"Three Unusual Strokes in a Triggered Lightning Flash", with V.P. Idone, **Journal of Geophysical Research**, (1984) in press.

"Ground Truth: A Positive Cloud-to-Ground Lightning Flash", with V.P. Idone and R.W. Henderson, Submitted to **Journal of Applied Meteorology**, September (1984), in press.

"Laboratory Simulation of Venusian Lightning", with W.J. Borucki, J.S. Levine, G.A. Harvey, and W.E. Howell, **Geophysical Research Letters, 10**, (1983), 961-964.

"Nighttime observations of thunderstorm electrical activity from a high altitude airplane", with M. Brook, C. Rhodes, O.H. Vaughan,Jr., and B. Vonnegut, **Journal of Geophysical Research**, (1984) under review.

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N84 34860 D31

TITLE: SEVERE STORM ELECTRICITY

RESEARCH INVESTIGATORS:

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Dr. Donald R. MacGorman, NOAA/NSSL,
Norman, OK 73069, (405) 360-3620
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Dr. Roy T. Arnold, UNIVERSITY OF MISS.,
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SIGNIFICANT ACCOMPLISHMENTS FY 84

During FY84, we have conducted a field program and analyzed data from previous years and from the spring of 83. The field program utilized coordinated measurements made with a NASA U2 and ground based facilities, both fixed-base and mobile. Aspects of this program are also reported by S. Goodman and R. Arnold elsewhere in this review. Portions of these and other efforts with which we were involved during the past year have yielded the following:

1) ground truth measurements of lightning for comparison with those obtained by the U2. These measurements have included flash type identification, electric field changes, optical waveforms, and ground strike location. Both sensors at NSSL and on the UM/NSSL mobile laboratory (see R.T. Arnold report) were used.

2) simultaneous ELF (extremely low frequency) waveforms at NSSL and MSFC for cloud-to-ground (CG) flashes. These are being used not only for flash identification but also examined for possible future combination with data from the proposed satellite lightning mapper.

3) an assessment of our CG strike location system (LLP) using a combination of mobile laboratory and NSSL television video data. This project is a few weeks from completion and now allows us to provide much more accurate locations of CG locations for comparison with the U2 data and for other storm research.

4) continued development of analog-to-digital conversion techniques for processing lightning data from the U2, mobile laboratory, and NSSL sensors. This hardware/software project is still underway, but already it has increased significantly our ability to look at large numbers of flashes. For example, we were able to study all flashes obtained at the U2 and the ground during the 3 June 83 flight chosen for analysis, not just a small percentage as in previous years. In addition the multi-channel capability allows us to compare easily various waveforms obtained simultaneously from the same flash, eg., field change and optical waveforms.

5) completion of an all-azimuth TV system for CG ground truth

6) a preliminary analysis of both IC and CG lightning in a mesocyclone (parent circulation of a tornado). We confirmed again our previously found relationship that CG activity increases after peak MC strength. In addition, we find the IC activity appears to peak at approximately the same time that the MC strength is a maximum.

7) the finding of a bimodal peak in altitude lightning activity in some storms in the Great Plains and on the east coast. In the storms on the Great Plains, there was a distinct class of flash that formed the upper mode of the distribution. These flashes had smaller horizontal extent, but occurred much more frequently than flashes in the lower mode of the distribution.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

We currently are completing preparations for the 1984 spring research program, with the U2 participating from mid-May to early June. A significant part of this program will be simultaneous data collection with sensors at NSSL, aboard the U2, and on the mobile laboratory. We anticipate completion in the near future of our analysis of site errors in our CG location network. We are completing our study of CG lightning in severe storms with a strong mesocyclone.

PLANS FOR FY 85:

We anticipate increased emphasis upon the combination of large meteorological and electrical data sets through cooperative work with MSFC as we explore interrelationships among electricity, precipitation, and air motions within severe storms. As data handling capabilities increase significantly at both locations, we anticipate being able to produce more case studies of severe storms. Other topics of ongoing research include positive CG flashes, continued evaluation of the ground strike locating system, particularly its ability to locate positive CG flashes.

RECOMMENDATIONS FOR NEW RESEARCH

We plan to expand our efforts to include identification of important scientific experiments that can best, or only, be conducted by using satellite mapper data to make a portion of the necessary measurements. Examples could include mapping of the horizontal progression of lightning that extends more than a hundred kilometers and the study of severe hail storms that produce mostly intracloud lightning. These latter plans are contingent upon renewal of our research proposal, which is currently in the review process.

PUBLICATIONS SINCE JUNE 1983:

Refereed

"Lightning flash density versus altitude and storm structure from observations with UHF- and S-band radars", Vladislav Mazur, J.C. Gerlach, and W. David Rust. Geophys. Res. Lttrs., 11, (1), 61-64, Jan. 1984.

"Positive cloud-to-ground lightning", W. David Rust. Submitted as a chapter in The Atmospheric Electrical Environment, Studies in Geophysics, National Academy of Sciences, 1983.

"Lightning activity and severe storm structure", William L. Taylor, Edward A. Brandes, W. David Rust, and Donald R. MacGorman. Accepted for publication in Geophys. Res. Lttrs. 1984.

Unrefereed

"Lightning activity observed in upper and lower portions of storms and its relationship to storm structure from VHF mapping and Doppler radar", William L. Taylor, W. David Rust, Donald R. MacGorman, and Edward A. Brandes. Preprints, 8th Inter. Aerosp. and Ground Conf. on Lightning and Static Elec., Ft. Worth, TX, June 21-23, 4-1 - 4-9, 1983.

"Lightning flash density versus altitude and storm structure from observations with UHF- and S-band radars", Vladislav Mazur, J.C. Gerlach, and W. David Rust. Preprints, Inter. Aerosp. and Ground conf. on Lightning and Static Elec., Ft. Worth, TX, June 21-23, 1983.

"Cloud-to-ground lightning in tornadic storms on 22 May 1981", Donald. R. MacGorman, W. David Rust, and William L. Taylor. Preprints, 13th Conf. on Severe Local Storms, Oct. 17-20, Tulsa, OK, 197-200, 1983.

"Relationships between lightning activity and severe storm structure from VHF mapping and Doppler radar", William L. Taylor, Edward A. Brandes, W. David Rust, and Donald R. MacGorman. Preprints, 13th Conf. on Severe Local Storms, Oct. 17-20, Tulsa, OK, 201-204, 1983.

"Cloud-to-ground lightning in the mesocyclone region of severe storms", S. Horsburg, R.T. Arnold, and W.D. Rust. Preprints, 13th Conf. on Severe Local Storms, Oct. 17-20, Tulsa, OK, 205-206, 1983.

"Positive cloud-to-ground lighting in severe storms and squall lines", W. David Rust, Donald R. MacGorman, and R.T. Arnold. Preprints, 13th Conf. on Severe Local Storms, Oct. 17-20, Tulsa, OK, 211-214, 1983.

"Lightning activity and mesocyclone evolution, 17 May 1981", Donald R MacGorman, Vladislav Mazur, R.T. Arnold. (Abstract) EOS, 64, (45), November, p. 662, 1983.

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D32

STUDIES OF LIGHTNING DATA IN CONJUNCTION WITH GEOSTATIONARY SATELLITE DATA

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Accomplishments in FY-84:

This study is not yet underway, but should begin shortly as funds are made available. Previous work on a related Center project has resulted in the archiving of Bureau of Land Management LLP data from the summer of 1983. There are also some geostationary three minute satellite images saved for this same period. These data are stored on magnetic tapes which can be processed and displayed on an interactive image processing system (McIDAS). The basic capabilities have also been developed for dial-in access to these data in real time as they become available from future storms.

Focus of Current Research Activities:

Over the next six months, much of our attention will go towards archiving a more complete data base upon which to perform our lightning studies. This effort will include:

(1) Continued archiving of Bureau of Land Management LLP, geostationary satellite, and NWS radar data, with special attention to suitable case study days; and,

(2) Expansion of the McIDAS real-time LLP access to other networks. Probable candidates for this expansion include the NSSL, NASA-Huntsville, and east coast SUNY networks.

At the same time, we will be developing additional processing tools for display and analysis of lightning location data in conjunction with geostationary satellite data. This effort will entail adapting existing McIDAS software to allow the production of statistical summaries and contouring of lightning characteristics over user defined areas or storms. We also want to be able to plot three-dimensional displays of lightning statisitics versus satellite and radar data; and to perform an error analysis of (and, if necessary, a correction algorithm for) lightning location data using overlapping regions of the BLM network.

Plans for FY-85:

Our effort in this period will be concentrated on relating satellite and radar observed storm features to lightning behavior. From satellite we can measure cloud top temperatures, anvil expansion, the locations of overshooting tops, and the evolution of all these characteristics over time. Radar adds additional information about rainfall intensity and cell structure. Using the data base and statistical techniques developed previously, we will be able to relate various measures of storm intensity and evolution to lightning location, frequency, flash multiplicity, and polarity.

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D33

Title: Lightning Observations from the Space Shuttle

Research Investigators:

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505-835-5611

Significant Accomplishments:

Motion pictures have been taken at night from the space shuttle that show lightning discharges spreading horizontally at speeds of 10^5 m sec^{-1} for distances over 60 km. Tape recordings have been made of the accompanying optical pulses detected with a photocell optical system. The observations show that lightning is often a mesoscale phenomenon that can convey large amounts of electric charge and energy derived from an extensive cloud system into a cloud-to-ground discharge.

Focus of Current Research Activities:

Several video tape recordings of lightning discharges have been obtained on shuttle flights since the termination of the NOSL program. The size and location of the lightning illuminated cloud images is now being analyzed, and comparisons are made with meteorological data concerning the cloud system obtained from the McIDAS.

Plans for FY-85:

Analysis of any lightning pictures taken during current space shuttle flights will be analyzed and correlated with McIDAS data. Experimental equipment will be devised for automatically recording on video tape images and optical signals produced by lightning. This equipment will then be engineered in cooperation with Marshall Space Flight Center for installation in a canister to be flown in the payload bay of the shuttle.

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II.B. AIRBORNE/GROUND-BASED DOPPLER LIDAR WIND RESEARCH

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N84 34863 D34

TITLE: Overview of Mesoscale Research Doppler Lidar Activities

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Significant Accomplishments to Date in FY84:

1. Analysis of 1981 ADLS flight data: Analysis of the data obtained in 1981 has continued. During FY84, ten scientists or groups were engaged in various aspects of the work. A number of publications, conference proceedings, and student theses have resulted and are listed elsewhere in this volume. In addition to this scientific work, and in keeping with the program goal of evaluating the performance of the airborne Doppler lidar system, a large number of deficiencies or mistakes have been identified in the original system and experiment plans. All of the known problems have been addressed and corrected in the planning and engineering for the fall 1984/spring 1985 ADLS flight series.

Thus, the most significant result of the data analysis has been the input it has provided to the preparations for the new experiment. Attitude measurement and beam pointing have been vastly improved. When these improvements are taken together with the streamlined operating procedures, color graphics realtime displays of data, and better experiment design, the result is a second-generation system that is considerably better than the one used in 1981. With any luck at all in the weather, we should be able to make some scientifically significant measurements in the new flight series.

2. Planning for 1984/1985 flight programs: A number of proposals have been received regarding the flights. The experiments include mesoscale flow and pollution transport, isolated mountain flows, sierra waves, marine boundary layer structure, severe storms, and flow about complex terrain. Planning has proceeded with ARC, and a tentative schedule has been prepared.

3. Ground-based lidar experiments: Data analyses by Rothermel and Emmitt are reported elsewhere in this volume. In addition to its scientific value, this work has been useful in adding to our understanding of the lidar system and in identifying hardware components that need to be overhauled before the new flight program.

Plans for FY85:

The flight meso experiments will start in August 1984 and end in September. The first portion of FY85 will thus be taken up with initial data analysis and system evaluation. We expect to have from the fall 1984 flights some quick-look publications and some preliminary wind fields before the start of the spring 1985 flights. The spring flights will be primarily mountain waves and severe storms. Following the flights there will be data evaluation, quick-look science, and the starting of scientific analysis of the data.

Recommendations for new research:

New research in this area should include additional scientific analysis of the data that we obtain in FY84 and FY85. We will expect to obtain considerably more than the initial research contracts can handle. Because of the considerable capability that has been developed, consideration should be given to the use of the lidar system in some of the field programs coming up in the next few years.

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AIRBORNE DOPPLER LIDAR

Analysis of 1981 Airborne Data

1. Radar lidar comparisons
   - a. Doviak et al., NSSL
     - o clear air, boundary layer
   - b. Srivastava, U. Chicago; Lee, Lassen Res.
     - o chaff, deep boundary layer
2. Gust fronts, outflows
   - a. Bluestein, et al., U. Okla
     - o NSSL radar
   - b. Emmitt, Simpson Assoc.
     - o CCOPE
3. Complex terrain
   - a. Cliff, et al., Battelle
     - o mountain pass, surface data
   - b. Carroll, UC Davis
     - o thermally forced mesoscale, tower
4. Cloud dynamics
   - a. Telford, DRI
     - o cloud turret
   - b. McCaul, U. Okla
     - o cloud edge entrainment

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DOPPLER LIDAR

Ground-Based Experiments

1. Rothermel, USRA
   - a. JAWS, Denver 1982
     - o Dual Doppler lidar
     - o Radar/lidar comparisons
   - b. MSFC, 1984
     - o Single Doppler winds
     - o Atmospheric backscatter
2. Frost, FWG Assoc.
   - a. MSFC, 1983
     - o Aircraft/lidar comparisons
     - o Gust probe, turbulence
3. Emmitt, Simpson Assoc.
   - a. JAWS, 1982
     - o complex terrain

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AIRBORNE DOPPLER LIDAR

- 1981 Flight Results:
  1. Science
  2. Improvements
     a. Experiment Design
     b. System
        Hardware and Software
        Preflight tests, calibration
     c. Data Analysis

⇒ SCIENCE

1. Analysis of wind data by 10 scientists/groups.
2. Feasibility demonstration.
   - Boundary layer structures
   - Gust Fronts
   - Measurement technique comparisons
   - Complex terrain

Airborne Doppler Lidar

Improvements in Experiment Design

- o CV990 operational limitations
- o Keep flight tracks simple
- o Avoid short, fragmented runs
- o Longer range with long pulse

Improvements in System

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1. Scanner control
2. Attitude measurement
3. System control
4. Data display
5. Optics/laser refurbishment
6. System sensitivity analysis

Scanner Control Improvements

1. Fast response to attitude change
   - o keep beam in desired plane
   - o reduce jitter within averages
   - o follow target at 10 deg/sec
   - o 1 deg change in 50 msec
2. Flexible scanning patterns
   - o more than 15 angles in 4 sec
   - o 180 deg scans at 2 Hz

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Airborne Doppler Lidar

▽ Attitude measurement improvements

1. 3 sources of roll,pitch,true heading
   - o new ADLS INU (20 Hz)
   - o CV990 INU
     aircraft interface (100 Hz)
     ADDAS (10 Hz)
2. 3 sources of drift angle,ground speed
   - o new ADLS INU (10Hz)
   - o CV990 INU (1 Hz)

▽ System Control Improvements

1. Data transfer
   - o async only
2. Simplified
   - o 1 computer with coprocessors
3. User friendly operation
   - o fast response to changing conditions
4. Additional data
   - o Navigational data at 10 Hz

▽ Data Display Improvements

1. Color line-of-sight scalar display
   - o velocity
   - o intensity
2. Time history of any variable
3. Vector field display

Airborne Doppler Lidar

Improvements in Preflight Tests, Calibration

1. System integration at MSFC
2. Simulation of flight
3. Calibration of system sensitivity
4. Beam pointing calibration
   - o preflight (MSFC)
   - o after CV990 installation (Ames)

Data Analysis Improvements

1. Keep MSFC product simple
   - o gridded line-of-sight winds
2. Look at low-level products first
   - o line-of-sight velocity
   - o intensity
   - o avoid vectors, vorticity, divergence
3. Use interactive graphics
   - o color spatial display of scalars

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TITLE: Analysis of Lidar, Radar, and Satellite Measurements on Severe Thunderstorms and Their Environments

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Significant Accomplishments to Date in FY-84:

Intercomparison of wind data from the airborne Doppler lidar, ground-based Doppler radars, the 444 m NSSL-KTVY tower, and rawinsonde has been completed. The vertical profile of wind in the PBL measured by the radars compared favorably with the profiles measured by the tower and rawinsonde while the one obtained from lidar data differed from the other three by as much as 3m/sec in wind speed and 38° in direction. The time dependence of differences in wind estimates from radar and lidar suggested that these discrepencies could be attributed to a Schuler resonance in the aircraft's inertial navigation system which caused an erroneous component of the aircraft's velocity vector to be subtracted from the lidar radial velocities, thus creating errors in the synthesized wind speed and direction. The vertical profile of turbulent fluctations of the horizontal wind detected by the different systems compared well. Also, spectra from the different sensing systems compared well in both magnitude and shape, suggesting that the lidar and radar detected similar turbulent structure.

This study has added to the documentation on the structure of the convective PBL. The vertically averaged winds over the PBL were found to be insensitive to baroclinicity, supporting the hypothesis of Arya and Wyngaard (1975). The computed momentum flux profiles were found to be in agreememt with those predicted by numerical models for the baroclinic, convective PBL. A consistent peak found near 4 km in all the

spectra computed from data collected on June 29, 1981 could be attributed to horizontally symmetric cells with horizontal wavelength 4 times the boundary layer height as theoretically shown by Kuettner (1971) for the case of weak wind shear.

Doppler lidar, aircraft, and surface mesonetwork data along two gust fronts were analyzed and examined. Wavelike patterns in the wind field appeared along one of the gust fronts. Doppler lidar data were analyzed at two levels in the area surrounding a growing, isolated, towering cumulus. The wind field was mainly convergent at both levels; the cloud was embedded within a line of convergence.

An observational study of a mesoscale area of convection in western Kansas has been completed, and it is hypothesized that the nocturnal thunderstorms were formed in response to lift (due to warm advection) of an elevated layer of conditional instability.

Focus of Current Research Activities:

Research is concluded and the final report is being prepared.

Plans for FY-85:

We look forward to participating in the FY '85 CV990 flights, data collection, and analyses.

Recommendations for New Research:

There is still an urgent need for the study of wind shear and the downburst phenomenon in connection with aircraft landing and take-off safety. Airborne Doppler lidar in conjunction with ground-based Doppler radars can be advantageously used for this study, and also for the study of the flow pattern in the vicinity of tornadoes, wall clouds, flanking lines, gust fronts, and pre-storm boundaries.

List of Publications Prepared since June 1983:

Bluestein, H.B., "An Observational Study of a Mesoscale area of Convection in Western Kansas" - submitted for publication in Monthly Weather Review.

Bluestein, H.B., E.W. McCaul, Jr., and D. Fitzjarrald, 1983: Airborne Doppler lidar and ground-based Doppler radar observations of a thunderstorm in Oklahoma. Preprints, 21st Conf. on Radar Meteorology (Edmonton), Amer. Meteor. Soc., 85-90. (cited previously)

Doviak, R.J., M. Eilts, and D. Fitzjarrald, "Remote and In-situ Observations of Atmospheric Winds and Turbulence Compared with Each Other and Theoretically Predicted Circulations" - Presented at the First Australian Conference on the Physics of Remote Sensing of Atmosphere and Ocean, Melbourne, Australia, 13-16 February 1984.

Eilts, M., 1983: "The Structure of the Convective Boundary Layer As Seen by Lidar and Doppler Radars". M.S. Thesis, University of Oklahoma, Norman, OK.

Eilts, M.D., A. Sundara-Rajan, and R.J. Doviak, "Boundary Layer Winds, Waves, and Turbulence Observed with Airborne Doppler Lidar and Ground-Based Dual Doppler Radars" - to be presented at the Twelfth International Laser Radar Conference to be held at Aux. En. Provence, France during 13-17 August 1984.

Eilts, M.D., R.J. Doviak and A. Sundara-Rajan, "The Structure of the Convective Atmospheric Boundary Layer As Revealed by Lidar and Doppler Radars" - submitted to Boundary-layer Meteorology.

Eilts, M.D., R.J. Doviak, and A. Sundara-Rajan, "Comparison of Winds, Waves, and Turbulence As Observed by Airborne Doppler Lidar, Ground Based Radars and Tall Tower" - submitted for publication in Radio Science.

McCaul, E.W., Jr., "Observations of Oklahoma convection using airborne Doppler lidar and Doppler radar", M.S. Thesis, University of Oklahoma, Norman, OK.

McCaul, E.W., Jr. and H. Bluestein, "Analysis of airborne Doppler lidar and ground-based Doppler radar observations of convection in Oklahoma" - to be submitted to J. Atmos. and Oceanic Tech.

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Research Summary Report

Evaluation of Airborne Doppler Lidar Wind Measurements

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FY-84 Accomplishments:

The primary thrust of this investigation continues to be the verification of the doppler lidar wind measurment system. It was intended that in situ measurements on a 500 meter tall tower would be used to check the lidar determined winds (flight 4), followed by other tests applied to the extensive data sets of flights 19 and 21. In fact, we have not been able to derive self consistent wind fields for any of these data. After checking for possible software errors in the processing programs at MSFC and at Davis, we have not been able to solve the inconsistency problem. The source of the errors appears to be the uncertainty in the calculation of the contribution of the aircraft motion to the lidar measured line of sight speed. Given that typical wind speeds are usually less than 20 knots whereas the aircraft travels at a minimum of 250 knots, most of the measured doppler speed is due to the aircraft motion. An error in either the ground speed or track angle results in an error in the calculated contribution of the aircraft motion to the line of sight speed. When the calculated aircraft induced component is subtracted from the measured doppler speed, this error is added to the contribution of the real wind. While the percentual error in the aircraft induced

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doppler speed is small relative to the aircraft speed, it is large relative to the wind speed.

The aircraft motion information is derived from the inertial navigation system (INS) in which errors of a knot in ground speed and a degree in track angle are not uncommon. For each one knot error in ground speed, the doppler derived wind speed will have an error between 0.05 and 1.0 knots in speed and up to 6° in direction depending on the wind direction relative to the flight path. For a track angle error of only 0.8 degrees, wind speed errors of up to 35% and direction errors in excess of 20° can be encountered with a mean wind of 10 knots. Again the error is dependent on the angle between the aircraft path and the wind direction. If wind field mapping with this technique is to be successful, errors in the aircraft motion must be less than 0.3 knots in speed and less than 0.1° in direction.

Current Research:

We are presently investigating possible techniques for estimating the aircraft motion errors from the aircraft data themselves. If this can be done, even for only certain very restricted circumstances, it would be useful for the design of future flight plans and experiments. We are also examining the suggestion of Dr. Fitzjarrald that ground returns be used in future flights to directly measure the aircraft contribution to the doppler measured speeds and make the subtraction of the aircraft induced component independent of the INS.

Plans for FY-85:

The current project will end by summer 1984. Our future plans are

to participate in the FY-85 flight program on the assumption that the problems identified here can be resolved. We will also be preparing a proposal to use this technique to obtain a detailed study of terrain modified sea breeze circulations from data obtained during the FY-85 flight program.

Publications:

On the accuracy of wind measurements using an airborne doppler lidar submitted to Jl of Atmos. and Oceanic Technology.

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TITLE: DOPPLER LIDAR RESULTS FROM THE SAN GORGONIO PASS EXPERIMENTS

RESEARCH INVESTIGATORS INVOLVED:

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SIGNIFICANT ACCOMPLISHMENTS: FY-84

During FY-84, the Doppler Lidar data from the San Gorgonio Pass experiments were analyzed, evaluated, and interpreted with regard to signal strength, signal width, magnitude and direction of velocity component and a goodness parameter associated with the expected noise level of the signal. From these parameters, a screening criteria was developed to eliminate questionable data. For the most part the author's analysis supports the validity of Doppler Lidar data obtained at San Gorgonio Pass with respect to the mean velocity magnitude and direction.

The question as to whether the Doppler width could be interpreted as a measure of the variance of the turbulence within the DLS focal volume was not resolved. The stochastic nature of the Doppler broadening from finite residence time of the particles in the beam as well as other Doppler broadening phenomenon tend to mask the Doppler spread associated with small scale turbulence. Future tests with longer pulses may assist in better understanding of this subject.

Data taken as the flow exits San Gorgonio Pass was used to calculate the following Spatial Auto Correlations.

- Longitudinal component longitudinal direction
- Longitudinal component lateral direction
- Lateral component lateral direction
- Lateral component longitudinal direction.

These auto-correlations were then used to compute the associated turbulent integral length scales. The Doppler Lidar data from Runs 13 and 14 of Flight 20 which were taken at elevations above grade of 800 and 850 meters respectively. Correlations of the data were performed using data that fell within a 100 meter-wide strip in the direction of interest.

The following is a table of the turbulent integral length scale for the longitudinal component longitudinal direction and for the lateral component lateral direction. The correlations were obtained from Flight 20 Run 13 at an elevation AGL of about 800 meters. Direct integration of the correlations as well as the Dryden approximation were used to compute the integral length scale.

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Flight 20 Run Number	Correlation Number	Longitudinal Component-Longitudinal Direction Integral Length Scale (Dryden Approx.) (Meters)	(Integration) (Meters)
13	1	200	164
13	2	350	239
13	3	420	328
13	4	220	134
13	5	400	343
13	6	580	388
13	7	220	194
13	8	220	194
13	9	300	209

Flight 20 Run Number	Correlation Number	Lateral Component-Lateral Direction Integral Length Scale (Dryden Approx.) (Meters)	(Integration) (Meters)
13	1	350	418
13	2	360	478
13	3	580	358
13	4	290	239
13	5	700	537
13	6	700	707

These results appear to indicate that the upper air where the correlations were obtained is tending toward isotropy. These length scales are reasonably close to values estimated in the open literature. It should be pointed out, however, that these data were taken in a region of expanding flow out of the pass. It should also be pointed out that these data are the only spatial data ever obtained over such a large area with such fine resolution.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Further examination of the detailed large scale turbulence with regard to its correlations, length scales, and spectra in the pass region is being studied. Areas where the flow is not accelerating are also under investigation. A test plan is also being developed which uses the NASA airborne DLS system to investigate the flow phenomena associated with large scale induced motions over and behind complex terrain.

RECOMMENDATIONS FOR NEW RESEARCH:

The NASA Doppler Lidar System should be used to investigate induced motions caused by complex terrain features extending into and through the boundary layer (e.g., such as the flow over an isolated hill which is within the main boundary layer and one that extends above the main boundary layer). The quantitative measure of the flow over and behind such objects would extend existing data bases on Strouhal vs. Reynolds No. and provide the scientific community with increased information on the physical processes which cause turbulence induced shedding.

Characterization of near surface flow patterns in regions of potential hazardous aerosol releases would be extremely useful in the development and verification of numerical diffusion models as well as for the safety analysis of the release of materials hazardous to personnel and/or the affected environment. In many locations of potential hazardous releases to the environment, little information is available as to the flow path that the release would take under prevailing wind conditions. Actual flow data would be valuable to validate or verify the models which are currently being considered for use.

LIST OF PUBLICATIONS IN FY-84

None. Spatial correlations and length scales being submitted to JAS.

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TITLE: ANALYSIS OF MSFC GROUND-BASED DOPPLER LIDAR DATA

INVESTIGATOR: Jeffry Rothermel
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Atmospheric Sciences Division
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Marshall Space Flight Center, AL 35812
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SIGNIFICANT ACCOMPLISHMENTS:

1. Analysis of data collected during the participation of the MSFC 10.6 micron pulsed Doppler lidar system (DLS) in the Joint Airport Weather Studies (JAWS) experiment is concluding. It was successfully demonstrated that observations from more than one Doppler lidar can be combined to derive the three-dimensional cartesian wind field. Several dual Doppler analyses (using data from the MSFC and NOAA/WPL lidars) were performed which depicted flow behind gust fronts. All were consistent with surface observations made by the NCAR Portable Automated Mesonet.

2. A comparison of radial velocity estimates at low elevations made by the MSFC lidar and the NCAR 5.5 cm Doppler radar (JAWS experiment) revealed a substantial r.m.s. difference of 3 m/s, and a mean difference of 1 m/s. Both measurement sets were taken within a cold air outflow produced by a squall line. Radar reflectivities were found to be below the level necessary for optimum performance of the radar signal processor; consequently, the radar radial velocity estimates were biased toward zero by ground clutter contamination. It is suggested that the action of the cold air outflow substantially reduced the number of flying insects originally present in the area. Insects are the predominant radar backscatterers at 5 cm, whereas the lidar relies upon the presence of naturally occurring aerosols.

3. Detailed measurements of horizontal wind fields and tropospheric backscatter have been acquired at MSFC during approximately 60 days of operation during the past twelve months. These data will be useful for defining future flight experiments, instrument design and satellite DLS development. The data, collected for a variety of atmospheric conditions, contain mesoscale and microscale phenomena of meteorological interest.

FOCUS OF CURRENT RESEARCH:

1. A study of the sampling characteristics of the MSFC DLS is in progress. Analysis has focussed on 1) a comparison with an instrumented tower, 2) along-wind versus cross-wind measurements, and 3) the effect of variable pulse length. Goals of the study are to 1) better understand DLS wind measurements that compare with traditional

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wind measurements, and 2) determine those aspects of DLS wind measurements which cannot be obtained from tradition techniques.

2. Work has begun on the analysis of data collected while the DLS was in the vertically scanning mode to determine vertical profiles of tropospheric backscatter and transmission loss. Preliminary results show that seasonal variations of backscatter observed at MSFC are consistent with previous studies. Moreover, sub-visible cirrus has been found to occur more frequently than heretofore expected. The results of this local study can be used to suggest that the performance of a spaceborne lidar may be better than thought at present.

PLANS FOR FY-1985:

1. Complete the analysis of wind velocity data collected by the MSFC DLS during JAWS. Identify and perform additional collocated comparisons where MSFC lidar and NCAR radar scans overlapped.
2. Complete the study of the sampling characteristics of the MSFC DLS described above. Continue to assess the capabilities and performance of the lidar as a viable mesoscale and microscale reseach tool.
3. Continue analysis of data collected at MSFC to determine tropospheric backscatter and transmission loss. Assess impact of resulting backscatter "climatology" on satellite DLS development.
4. Initiate analysis of MSFC data sets collected during JAWS to determine vertical profiles of backscatter and transmission loss.
5. Demonstrate feasibility of retrieving horizontal winds using only single ground-based Doppler lidar radial velocities. It is proposed that the technique of correlation analysis be used. Several candidate data sets from JAWS and from the ground-based series of experiments at MSFC have been identified for analysis.
6. Participate in the Fall 1984 airborne DLS flight series.

PUBLICATIONS:

Rothermel, J. and D.E. Fitzjarrald, 1983: Dual Doppler lidar measurements of winds in the JAWS experiment. Preprints, 21st Radar Meteor. Conf., Edmonton, Alta., Amer. Meteor. Soc., 579-583.

Rothermel, J., R.M. Hardesty and C. Kessinger, 1983: Dual-Doppler analysis of lidar measurements taken during JAWS. Technical Digest, 2nd Topical Meeting on Coherent Laser Radar, Aspen.

Submitted:

Rothermel, J., C. Kessinger and D.L. Davis: Dual Doppler lidar measurements of winds in the JAWS experiment. J. Atmos. Oceanic Tech.

In Preparation:

Jones, W.D., J. Rothermel and D.E. Fitzjarrald: Ground-based measurements of atmospheric backscatter at CO2 wavelengths. To be submitted to Appl. Optics.

Rothermel, J. and G.D. Emmitt: Sampling characteristics of pulsed CO2 Doppler lidar: ground-based studies. To be submitted to J. Atmos. Oceanic Tech.

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1. Title: Analysis of Doppler Lidar Wind Measurements

2. Research Investigators Involved:

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3. Significant Accomplishments:

New analysis methods were developed and refined for the synthesis of wind fields from multiple Doppler radar data. Considerable software was written and debugged for wind field synthesis. The analysis methods have been applied to radar data collected during the CCOPE experiment in which lidar wind measurements were also made.

The analysis method differs from existing methods in that interpolation (using filters with assigned weights) and advection of data, to account for time differential between data acquisition at different points, are not used. Instead, we use functional fits in space and time coordinates to transfer radial velocity data to a space-time grid. Subsequently the wind synthesis is performed. This method gives better space resolution in the synthesized winds, compared to other methods in common use, by better preserving the gradients of velocities.

The CCOPE Doppler radar data analyzed pertain to observations in the clear air in the well-mixed convective boundary layer. Radar chaff was used as a tracer of the air motions. A few sample wind fields obtained by the method are shown. THe radar baselines are shown by the straight lines.

The wind fields show the cellular structure characteristic of boundary-layer convection. Also evident in the analysis are the sharp transitions and gradients in the wind field which have been preserved by the systhesis.

4. Focus of Current Research Activities:

- Compilation of a complete set of high resolution wind data, similar to the ones attached, from an analysis of the radar data.
- Calculations of divergence and vertical air velocity fields.
- Calculation of trajectories of air particles.

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5. **Plans for FY-85:**

- Interpretation of the above wind data in terms of the physics of turbulent convection in the boundary layer.
- Spectral and moment transport characteristics of the wind field may be calculated.
- An attempt may also be made to retrieve thermodynamic data from the time sequence of the high resolution wind fields.

6. **Recommendations for New Research:**

a. Study of the detailed wind structure in the vicinity of an evolving inversion in the lower atmosphere. The lidar measurements should be supplemented by measurements by microwave radar and high resolution profiling of thermodynamic parameters, and perhaps other quantities.

b. Mapping of the wind structure in 'generating' cells. Again, the measurements should be supplemented by microwave radar measurements.

7. **List of Publications Prepared Since June 83:**

None. However, one is planned after 4 above is completed.

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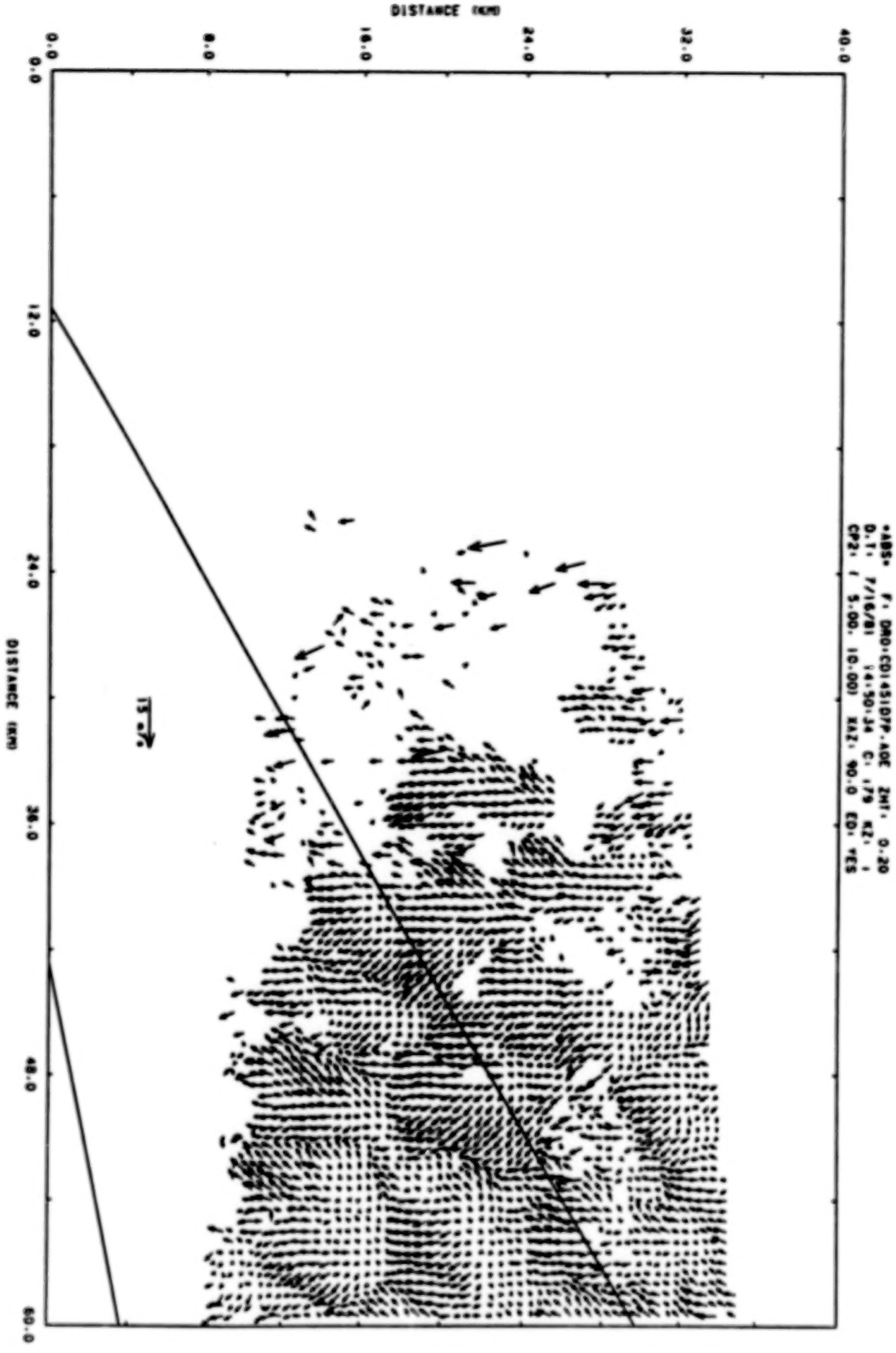

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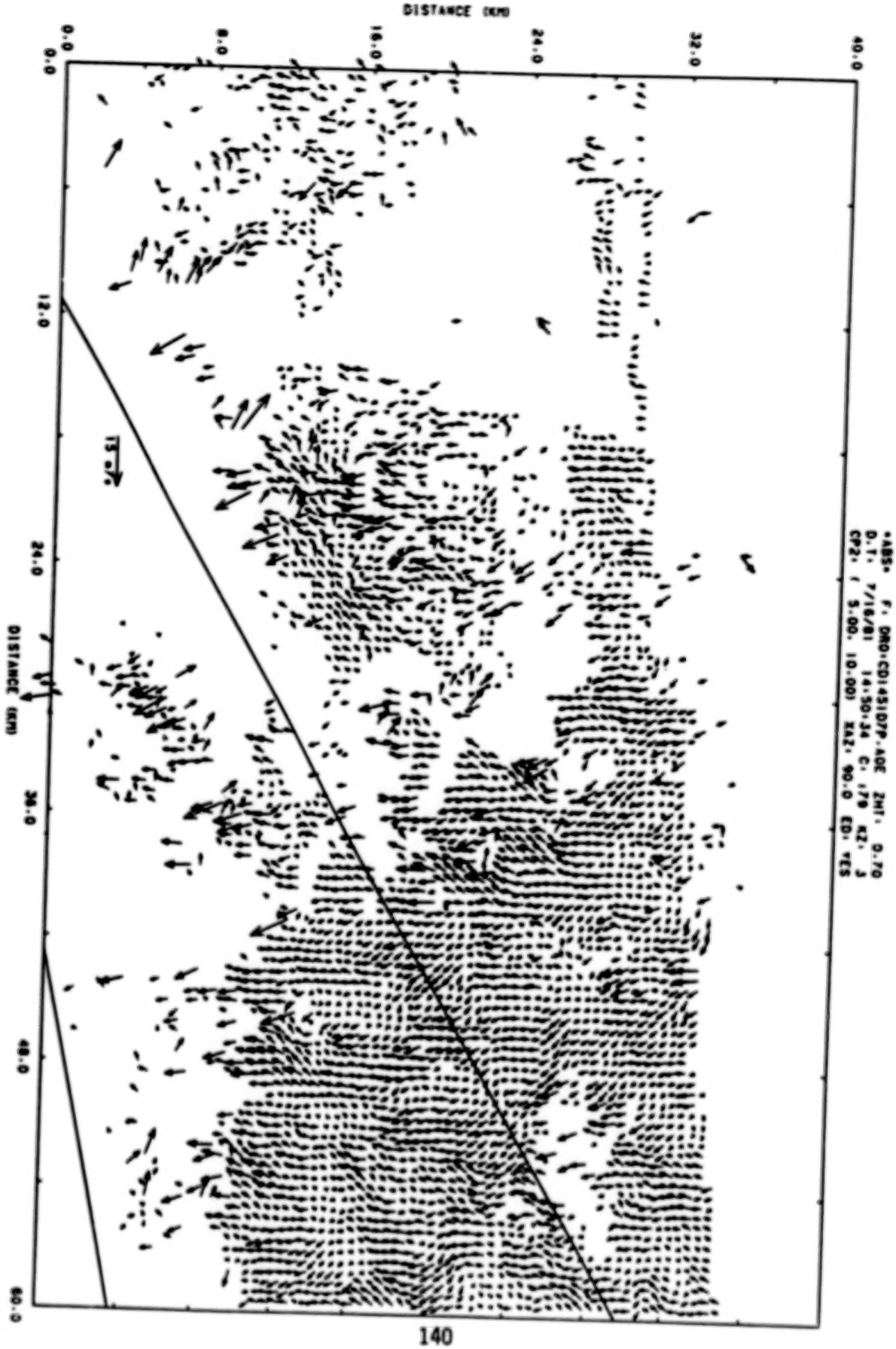

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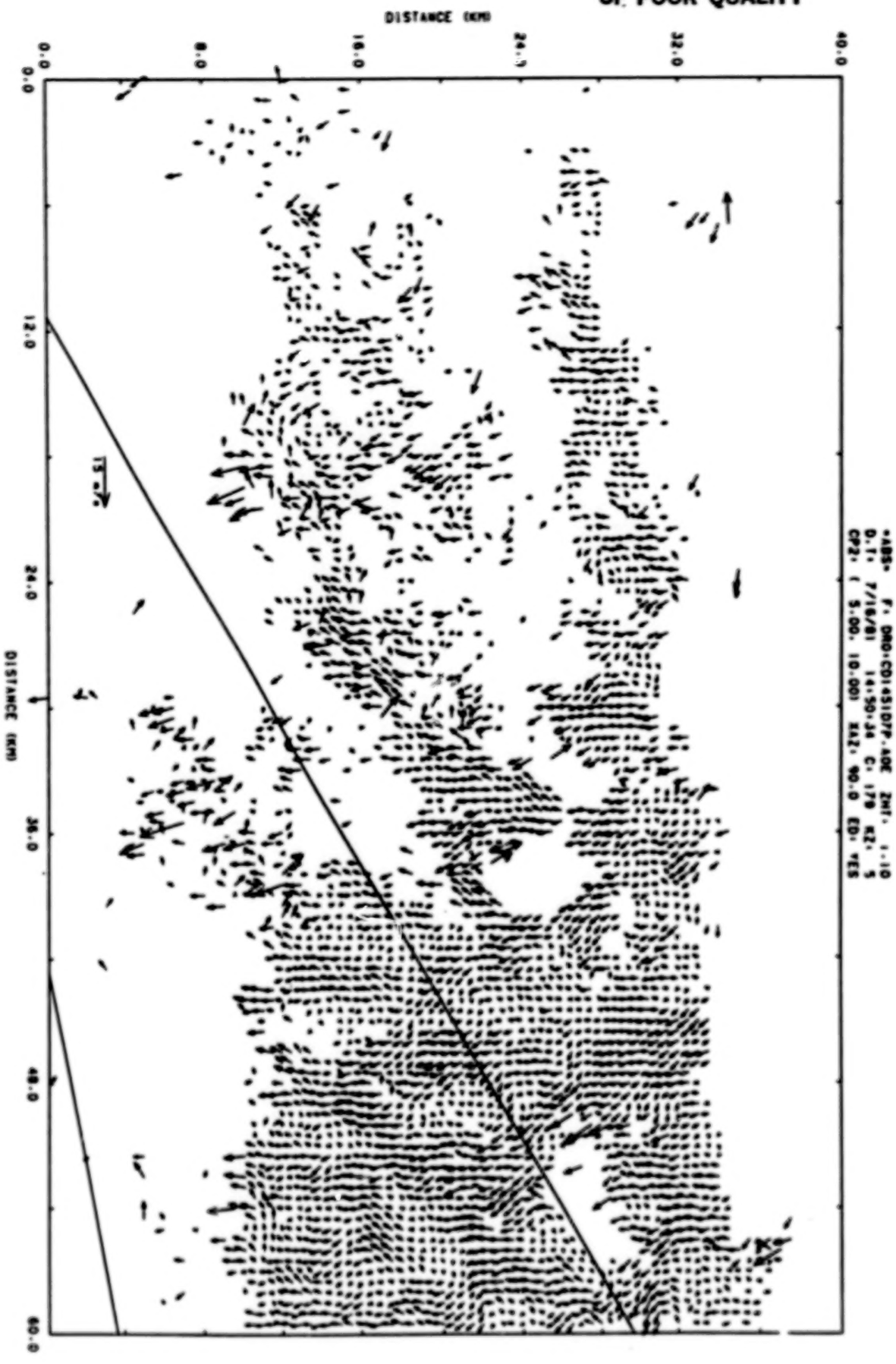

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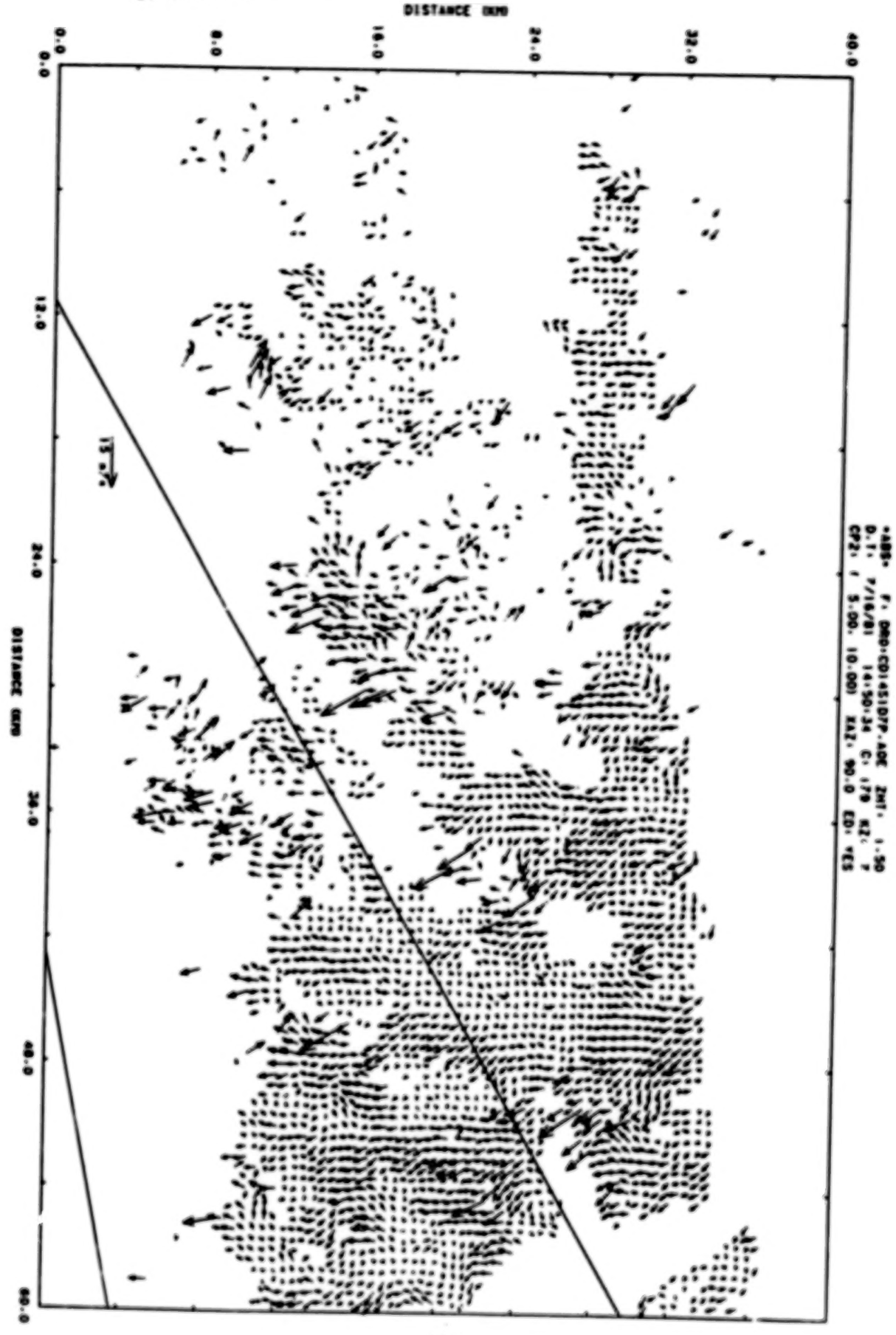

II.C. MESOSCALE ANALYSIS AND SPACE SENSORS

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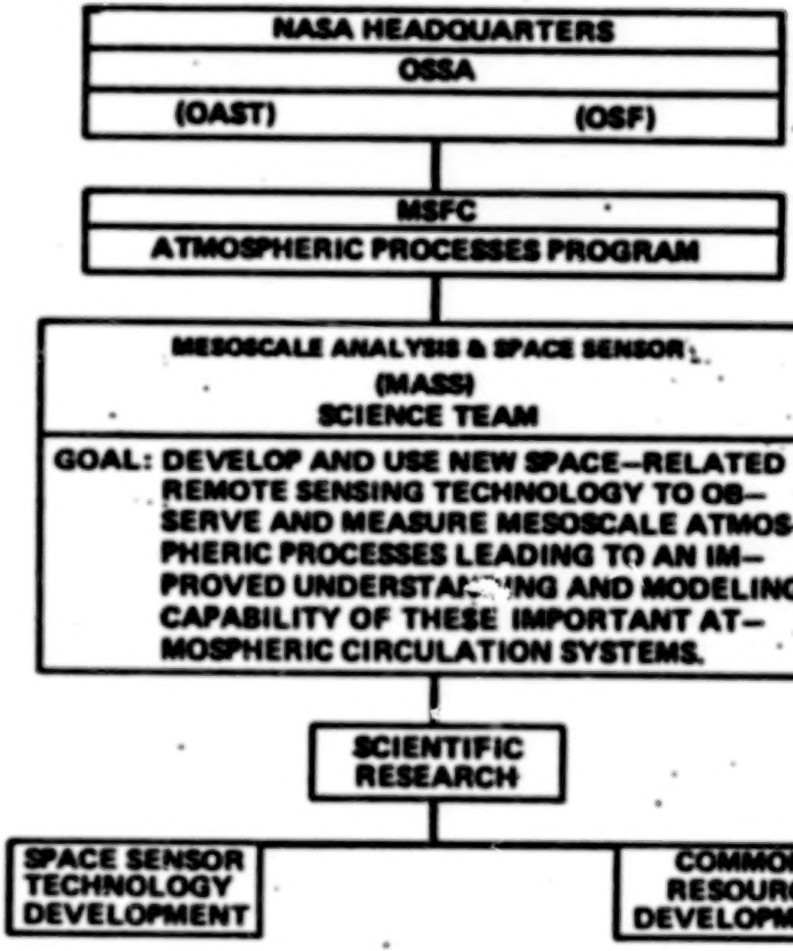
ATMOSPHERIC SCIENCES DIVISION

Mesoscale Analysis and Space Sensor Program

PROGRAM STRUCTURE AND GOALS


NASA HEADQUARTERS
OSSA
(OAST)
(OSF)
MSFC
ATMOSPHERIC PROCESSES PROGRAM
MESOSCALE ANALYSIS & SPACE SENSOR
(MASS)
SCIENCE TEAM
GOAL: DEVELOP AND USE NEW SPACE–RELATED REMOTE SENSING TECHNOLOGY TO OBSERVE AND MEASURE MESOSCALE ATMOSPHERIC PROCESSES LEADING TO AN IMPROVED UNDERSTANDING AND MODELING CAPABILITY OF THESE IMPORTANT ATMOSPHERIC CIRCULATION SYSTEMS.
SCIENTIFIC RESEARCH
SPACE SENSOR TECHNOLOGY DEVELOPMENT
COMMON RESOURCE DEVELOPMENT

PARTICIPANTS

IN–HOUSE	UNIVERSITY			GOVERNMENT/OTHER		
CIVIL SERVICE	TAMU	SLU	U. OF WIS.	NESDIS	NSSL	WPL
USRA SCIENTISTS	PURDUE	PENN ST.	CSU	TVA	NCAR	ERL
SUPPORT CONTRACTORS	SD	DREXEL	U. OF VA.	NSSFC	NWS	GSFC
	UAH	U. OF CHICAGO		AMES		

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ATMOSPHERIC SCIENCES DIVISION

ATMOSPHERIC PROCESSES'
Mesoscale Analysis and Space Sensor

(MASS)

PROGRAM OVERVIEW

GREGORY S. WILSON

MAY 1984

RESEARCH
PROGRAM FOCUS AND ELEMENTS

FOCUS: TO BETTER UNDERSTAND AND MODEL THE MESOSCALE STRUCTURE AND DYNAMICS OF THE ATMOSPHERE IN RELATION TO CLOUD/PRECIPITATION/LIGHTNING PHENOMENA USING UNIQUE SPACE MEASUREMENTS.

RELATED SPACE SENSOR TECHNOLOGY DEVELOPMENT 3

- VAS
- HIS
- DLS
- LIMS
- SASE
- MAMS
- WINDSAT
- LARS
- EOM

FUNDAMENTAL SCIENTIFIC RESEARCH 1

SCIENCE WORKING GROUPS

MESOSCALE ENVIRONMENT
(1 km < SYSTEMS < 5000 km)

SCALE INTERACTION

PRECIPITATION/CLOUDS/LIGHTNING
(SYSTEMS > 1 km DIAM.)

COMMON RESOURCE DEVELOPMENT 2

- COMPUTER/DBM SYSTEMS
- GROUND TRUTH FIELD EQUIP.
- AVE MESOSCALE DATA SETS
- GOES IMAGE ARCHIVE
- 4-D DATA ANALYSIS SYSTEM

1. MEASUREMENT OF KEY VARIABLES
   (REMOTE ATMOSPHERIC MEASUREMENTS AND ANALYTICAL TECHNIQUE DEVELOPMENT)
2. IMPROVED UNDERSTANDING
   (DIAGNOSTIC/THEORETICAL ANALYSES AND DATA ASSIMILATION)
3. DYNAMICAL AND PHYSICAL MODELS
   MODEL DEVELOPMENT, ATMOSPHERIC SIMULATIONS, AND NON-LINEAR SCALE-INTERACTION PROBLEMS)

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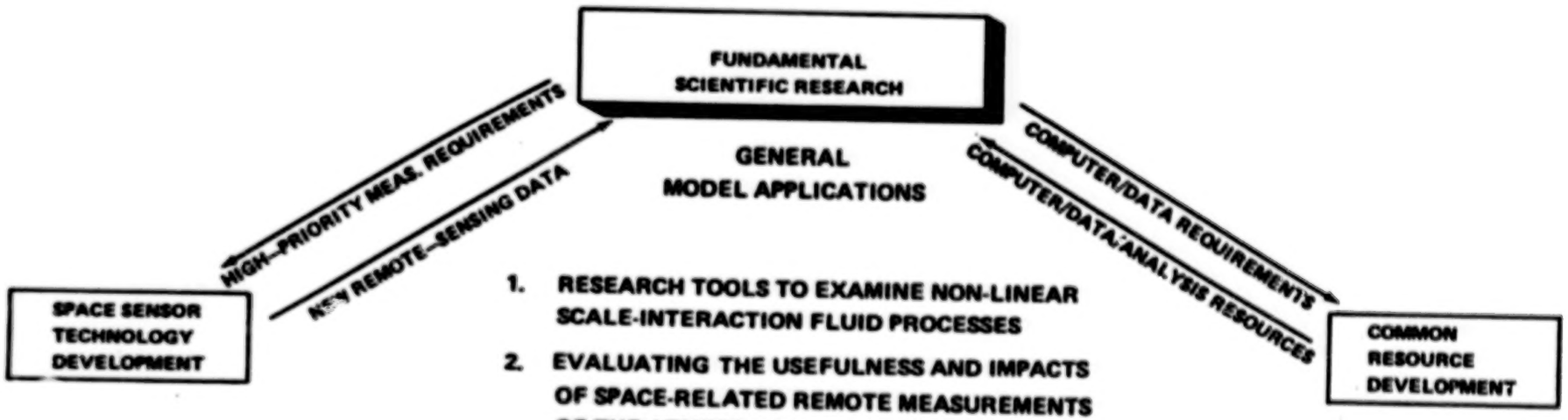
DESCRIPTION OF MASS MODELING

JUSTIFICATION: COMPUTATIONAL FLUID MODELING OF MESOSCALE AND RELATED ATMOSPHERIC PHENOMENA IS CONDUCTED AS AN INTEGRAL PART OF FUNDAMENTAL MASS SCIENTIFIC RESEARCH AS SHOWN BELOW:



1. RESEARCH TOOLS TO EXAMINE NON-LINEAR SCALE-INTERACTION FLUID PROCESSES
2. EVALUATING THE USEFULNESS AND IMPACTS OF SPACE-RELATED REMOTE MEASUREMENTS OF THE ATMOSPHERE
3. ATMOSPHERIC SIMULATIONS AND PREDICTIONS

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RECOMMENDED PROGRAM IMPROVEMENTS
FY 84 – 86
MASS SCIENCE TEAM

FUNDAMENTAL SCIENTIFIC RESEARCH:

- SUPPORT THEORETICAL AND MODELING RESEARCH AT MSFC PERTAINING TO MESOSCALE CONVECTIVE PRECIPITATION (i.e., FRITSCH AND McNIDER PROPOSALS)
- ESTABLISH ON RTOP–FUNDED MICROWAVE PRECIPITATION ACTIVITY

COMMON RESOURCE DEVELOPMENT

- BUILD 4–D, NEXT–GENERATION McIDAS TERMINAL PROTOTYPE USING RESULTS OF THE COMPLETED DESIGN REQUIREMENTS STUDY.
- SUPPORT THE MSFC SPACE ((SATELLITE PRECIPITATION AND CLOUD EXPERIMENT) FIELD PROGRAM TO BE CONDUCTED BETWEEN JANUARY 1986 – MAY 1987. ENCOURAGE WIDEST POSSIBLE CO–PARTICIPATION INCLUDING MIST, GALE, FIRE ETC.

SPACE SENSOR TECHNOLOGY DEVELOPMENT

- SUPPORT THE AIRCRAFT/SHUTTLE DESIGN STUDIES FOR THE MAMS (MULTISPECTRAL ATMOSPHERIC MAPPING SENSOR)
- EXPAND THE EARTH OBSERVATION MISSION (EOM) CONCEPT TO INCLUDE LOWER ATMO–SPHERIC AS WELL AS UPPER ATMOSPHERIC/SOLAR SCIENCE ISSUES AND INSTRUMENT COM–PLIMENTS.
- EXTEND THE EOM CONCEPT TO INCLUDE THE FOLLOW–ON DEVELOPMENT OF A NASA RESEARCH GEOSTATIONARY SATELLITE.

II.C.1. THE MESOSCALE ENVIRONMENT AND MODELING

Title: Investigations of the Arc-Cloud Complex

Investigator: Kenneth C. Brundidge
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Significant Accomplishments to Date in FY-84:

1. The study of the arc-cloud complex case of 17 May, 1982 was expanded upon by procurement of the hourly rainfall data for the climatological network over Texas. These data are being plotted and analyzed. Comparisons are being made with Radar Summary reports, satellite images and hourly surface data analyses to determine what connection there may be between rainfall rates and patterns, and arc-cloud formation.

2. The case of 26 June, 1982 has been given a thorough study. It is in the process of being written up as the M.S. thesis of Captain Robert L. Miller, USAF.

Focus of Current Research Activities: The studies mentioned above are ongoing.

Plans for FY-85: Future work will depend upon procurement of funding.

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Regional Scale Numerical Simulation of Atmospheric Structure Using VAS Data

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INTRODUCTION

This investigation, which began in July 1983, is targeted at three days in spring 1982, March 6 and April 24, which were AVE/VAS days, and April 26, a day of significant severe weather. To date, experiments have been run on the cases of March 6 and April 26 with the Subsynoptic Scale Model (SSM), with April 24 yet to be investigated in FY 84. A parallel investigation using the Limited Area Mesoscale Prediction System (LAMPS) has been slowed due to a computer change at NCAR from its CDC 7600 to a second CRAY, since LAMPS had been designed to use the 7600 as a front end. The problem was amplified because the Drexel University group (Perkoy, Kreitzberg, and Chang) which had developed the model were not actively maintaining it in FY 84.

Investigations with both SSM and LAMPS are directed at model static initializations using VAS derived temperatures and moistures and also satellite derived winds. The general approach for each day's case study is similar. A 12-hour control forecast (no satellite data) is made 12Z-0Z, using a radiosonde analysis at 12Z as the initial field. For the satellite data experiments, reanalyses are performed at intermediate times, using VAS soundings or VAS soundings in combination with satellite winds. Forecasts are subsequently made from the reanalysis time(s) to the same validation hour (0Z) as the control forecasts. Comparisons are then made between the control forecast and satellite experiments.

ACCOMPLISHMENTS TO DATE IN FY 84

The most interesting and significant results to date have been obtained from the SSM for the April 26 case study. The satellite data for this day is unique in the four VAS sounding data sets which are available (16Z, 17Z, 19Z, 21Z) from which to reinitialize forecasts. Forecasts from each of these times to the 0Z validation hour show good consistency in the primary fields and also derived parameters such as vertical motion, skill scores, and stability indices. Consistency and comparable skill with the control forecast are evident.

A significant feature in this work has been the complementary nature of the VAS soundings and satellite winds in the SSM analysis scheme, a variational approach which uses measured winds as an indicator of height gradients. Often in areas associated with significant weather, clouds are responsible for large areas devoid of satellite soundings which can be analyzed using cloud drift and water vapor winds in the variational analysis approach. Forecasts for April 26 using both satellite soundings and winds have demonstrated the utility of using those two data forms in concert.

FOCUS OF CURRENT RESEARCH ACTIVITIES

A similar approach (i.e., using both satellite winds and VAS soundings) will be applied to the other two days being investigated. We will be re-running March 6, a day where gaps in the VAS soundings made analyses particularly difficult. Initial comparisons of control of a control forecast and forecasts using satellite soundings alone were inconclusive on this day. We expect that including the satellite winds will enhance the analyses and forecasts for this day. Current research activities for the LAMPS include running a control forecast for March 6 and duplicating the SSM forecast sequence for this day and for April 24.

PLANS FOR FY 85 AND RECOMMENDATIONS FOR NEW RESEARCH

The modelling effort for FY 85 will focus on three areas of interest:

1. the importance of mesoscale moisture information in the forecasting of weather events and the suitability of the VAS in providing this data,

2. the importance of satellite-derived winds in combination with conventional and satellite sounding information in representing mesoscale detail of the initial state from which forecasts are made, and

3. the implementation of a data assimilation scheme which preserves the divergent component of the wind to enable meaningful short-term (less than 4 hour) mesoscale forecasts to be achieved with the SSM and LAMPS.

PUBLICATIONS

A publication on the SSM investigation of April 26 is in preparation for Monthly Weather Review.

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Title: Statistical Analysis and Use of VAS Radiance Data

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Contributors: Carol Belt, Ted Funk, Matt Printy, Mike Remeika, Mark Ruminski, Mike Stewart

Significant Accomplishments to Date in FY-84:

A. Several tasks were completed as part of the contract that expired in March 1984. The focus of that effort was to better understand causes for intense convection along with its impact on the surrounding environment.

1) Our investigation of the AVE-SESAME V period (20-21 May 1979) was very successful. Special radiosonde soundings at 75 km spacings and 3 h intervals provided a unique opportunity to learn more about mesoscale data and storm-environment interactions. Results proved that relatively small areas of intense convection produce major changes in surrounding fields of thermodynamic, kinematic, and energy variables. Three publications describing these efforts were prepared.

2) We continued to study the Red River Valley tornado outbreak (10-11 April 1979, AVE-SESAME I). Generation of available potential energy (APE) by five diabatic components was computed as an extension of our earlier investigation of kinetic energy during the same period. A unique aspect to the research was that satellite imagery and surface data were used to specify cloud information needed in the radiative heating/cooling calculations. Also, the radiative transfer models were more sophisticated than those used in previous APE investigations. Results showed that convective latent heat release was the major diabatic component and generator of APE. Infrared cooling was the second greatest contributor. The findings suggest that radiative processes may have a greater influence on the atmosphere's APE generation than was previously realized.

3) We completed a feasibility study for computing boundary layer winds from satellite-derived thermal data, and results were very encouraging. Winds in the lowest 1600 m AGL were diagnosed via Ekman relations similar to those contained in the Air Force's Boundary Layer Model. Winds obtained from TIROS-N retrievals compared very favorably with corresponding values from concurrent rawinsonde thermal data, and both sets of thermally-derived winds showed good agreements with the observed values. Fields of various kinematic parameters (e.g., moisture convergence, vertical motion, vorticity) derived from the satellite data were very similar to those from the rawinsonde thermal data (Fig. 1). In addition, the patterns agreed with the locations of convection that developed later in the day. Thus, this procedure for estimating low-level winds may have useful forecasting applications.

B. Our new contract began in September 1983, and its focus is to provide better understanding and utilization of VAS radiances and retrieved soundings. Although this effort is still quite new, we are making substantial progress.

1) Fuelberg spent his Fall 1983 sabbatical leave in residence at NASA/Marshall. A one week period at the University of Wisconsin also was included. The sabbatical was very fruitful since it provided time to read and plan for the new efforts. By having access to Marshall's McIDAS terminal, "hands-on" experience with VAS imagery was available in a timely manner. Finally, the visits provided opportunities to discuss our ideas with other scientists.

2) We are well into the investigation of data from the 6.7 μm water vapor

channel of VAS. By considering the 6-7 March day of the 1982 AVE-VAS Field Experiment, we are able to evaluate mesoscale radiance features with those from the special mesoscale radiosonde network in central Texas. Thus far, we have emphasized comparisons between the two data sources, but we are about to seek explanations for the observed radiance patterns. The 6.7 μm radiances are affected by humidity and temperature, and the level of the vapor features also is a key factor. Thus, this effort promises to be challenging, but with the potential for important applications.

3) We are conducting a case study of a convective outbreak during July 1982. VAS retrievals were available at mesoscale spacings for six times over a 12 h period. The soundings were carefully evaluated, edited, and then objectively analyzed to provide meso α- scale resolution. The resulting patterns demonstrate that VAS soundings can yield good continuity of features. From the gridded data, we have computed thermodynamic parameters including thickness, stability indices, and precipitable water. All results are being compared with those from the routine 12 h NWS radiosonde releases. Our goals are 1) to evaluate the usefulness of VAS data in describing conditions after 1200 GMT that lead to the convection, and 2) to investigate new applications for the retrievals.

Focus of Current Research Activities:

Explanations for patterns in the 6.7 μm data are being sought. The special mesoscale radiosonde data are being objectively analyzed so that kinematic parameters such as deformation, vertical motion, and vorticity can be calculated. Prior studies have shown that these quantities relate to the water vapor image features.

Concerning our case study, a report on the results to date is being prepared. It will document procedures and describe findings relating the thermodynamic variables to the thunderstorm activity. We are beginning to compute geostrophic winds from the VAS thermal data. Our ultimate goal here is to investigate whether VAS retrievals can be used to estimate vertical motions via the adiabatic method or the omega equation.

Plans are underway to investigate the physical retrieval procedure. We will compare the information content of the first guess and radiance data with that of the final VAS soundings. Our goal is to better understand the algorithms and assess the utility of using radiances directly as a supplement to the retrieved soundings. Data for this task are being collected, and computational procedures are being planned.

Plans for FY-85:

We will continue the efforts of the first year. Specifically, we will perform trajectory analyses to better understand the patterns in 6.7 μm imagery during 6-7 March 1982. Satellite-derived vertical motions will be obtained from several procedures for our case study. Finally, the information contents of VAS radiances and first guess data will be evaluated against those of the retrieved soundings. At least two journal manuscripts will be submitted on results from the recently expired contract.

Recommendations for New Research:

First, based on one set of TIROS-N retrievals, it seems feasible to calculate boundary layer winds from satellite thermal data. Now that VAS soundings are available at relatively short time intervals, the utility of this technique should be tested in a pre-convective environment to determine if there is potential for severe storm forecasting. Second, most applications of satellite data have been patterned after those using radiosonde information. Since satellite data are fundamentally different, however, we should focus on the development of new techniques that make use of the satellite's particular strengths, but are not overly dependent on its limitations.

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Publications Since June 1983:

Belt, C. L., and H. E. Fuelberg, 1984: A diagnostic approach to obtaining planetary boundary layer winds using satellite-derived thermal data. NASA Contractor Report, in press.

Buechler, D. E., and H. E. Fuelberg, 1983: The formation of upper level wind maxima near convective complexes. Preprints Thirteenth Conf. Severe Local Storms, Tulsa, Amer. Meteor. Soc., 292-295.

Fuelberg, H. E., and P. A. Browning, 1983: Roles of divergent and rotational winds in the kinetic energy balance during intense convective activity. Mon. Wea. Rev., 111, 2176-2193.

Fuelberg, H. E., and M. F. Printy, 1983: Meso β- scale thunderstorm/environment interactions during AVE-SESAME V (20-21 May 1979). Bull. Amer. Meteor. Soc., 64, 1144-1156.

Fuelberg, H. E., and M. F. Printy, 1984a: A kinetic energy study of the meso β-scale storm environment during AVE-SESAME V (20-21 May 1979). NASA Contractor Report, in press.

Fuelberg, H. E., and M. F. Printy, 1984b: A kinetic energy analysis of the meso β-scale severe storm environment. J. Atmos. Sci., Conditionally accepted.

Ruminski, M. G., 1984: Generation of available potential energy during the AVE-SESAME I period. M.S. Thesis, Saint Louis University, 95 pp.

Ruminski, M. G., and H. E. Fuelberg, 1983: A subsynoptic scale analysis of available potential energy generation during a tornado outbreak. Preprints Thirteenth Conf. Severe Local Storms, Tulsa, Amer. Meteor. Soc., 358-361.

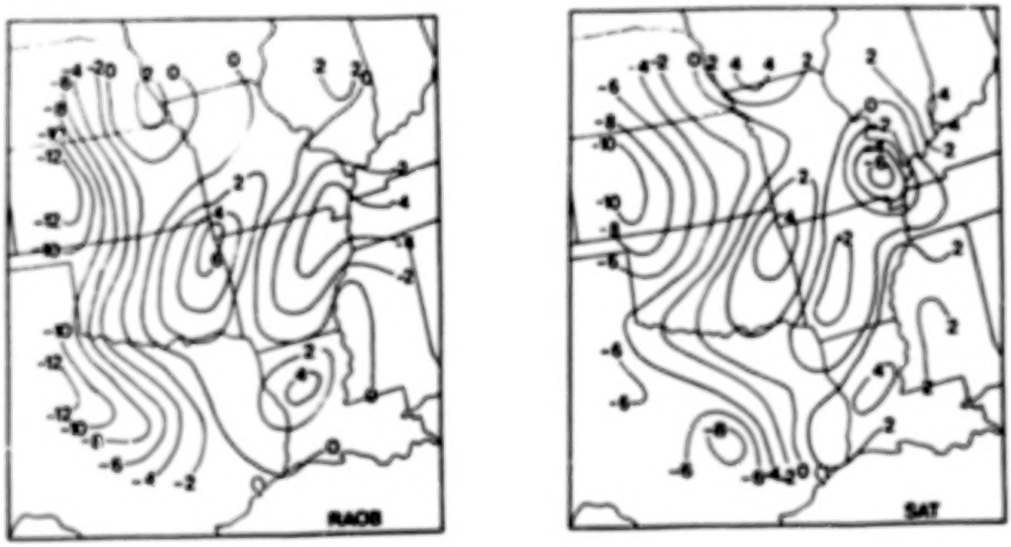

Fig. 1. Moisture divergence (10^{-4} g kg^{-1} s^{-1}) from RAOB- and satellite-derived Ekman winds at 300 m AGL for 0921 GMT 19 April 1979.

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TITLE: Mesoscale and Severe Storms (MASS) Data Management and Analysis System

Research Investigators: John S. Hickey, Shogo Karitani, Mike Dickerson
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Huntsville, Alabama 35801 (205/533-7590)

Significant Accomplishments - FY84:

DATA BASE MANAGEMENT: An interactive atmospheric data base management software package to convert four types of data (Sounding, Single Level, Grid, Image) into standard random access formats has been implemented and integrated with the MASS AVE80 Series general purpose plotting and graphics display data analysis software package.

ANALYSIS AND DISPLAY: An interactive analysis and display graphics software package (AVE80) to analyze large volumes of conventional and satellite derived meteorological data has been enhanced to provide imaging/color graphics display utilizing color video hardware integrated into the MASS computer system. Local and remote smart-terminal capability has been provided by installing APPLE III computer systems within individual scientist offices and integrated with the MASS system, thus providing color video display, graphics, and characters dispaly of the four data types.

Current Focus of Research Work:

Currently, the existing atmospheric software (AVE80 series) and data sets are being upgraded to enhance the capabilites by using the APPLE III computers integrated with the MASS HP-1000F, Perkin-Elmer 3252, and the McIDAS-HARRIS/6 computer systems.

Plans for FY85:

Software Modification--

- Provide software capability to transfer four MASS data types from HP-1000 to the HARRIS/McIDAS and Perkin-Elmer 3252 computers.
- Provide video, graphics, and character display of MASS data using APPLE III terminals integrated with Perkin-Elmer and HARRIS/6 computers.
- Extend the data base management to analyze LLP lightning data, TVA and NCC rainfall data, MDR digital radar data, and VAS multispectral imagery.

Hardware Modification--

- Additional APPLE III computer systems will be installed to expand the current remote terminal capability.
- An HP 400 mega-byte disc drive will be installed to allow for expanded capabilites for processing large volumes of satellite and radar data.

Recommendations for New Research:

To continue modifying the atmoshperic software and data sets to provide for enhanced capabilities via the integration of the MASS HP-1000, Perkin-Elmer, and HARRIS/McIDAS computer systems. In addition, to upgrade MASS HP-1000 Operating System from RTE-IVB to RTE-VI and Graphics 1000 software package to Graphics II, which would improve the overall research environment.

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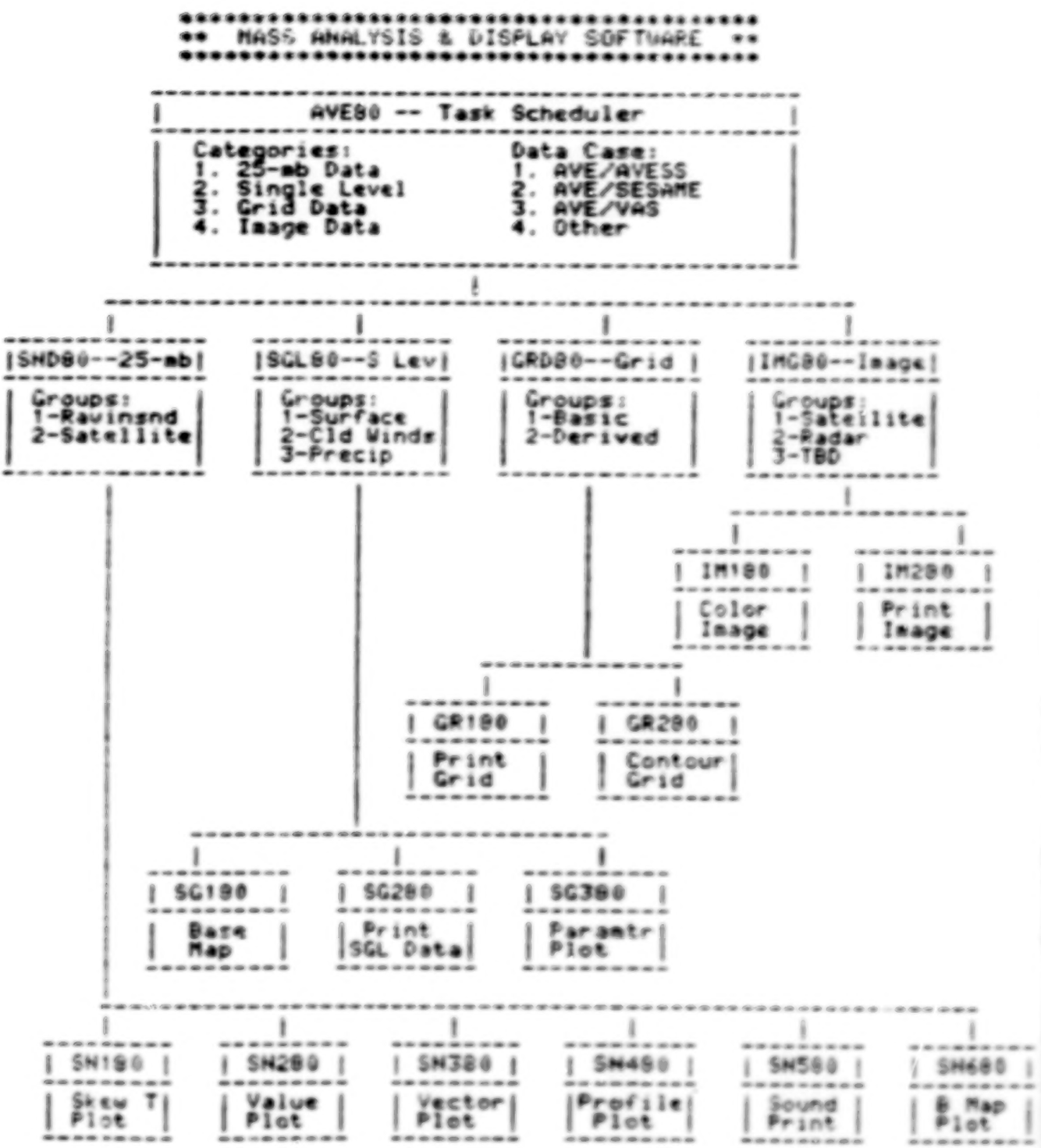

Detailed Flowchart of MASS AVE80 Software

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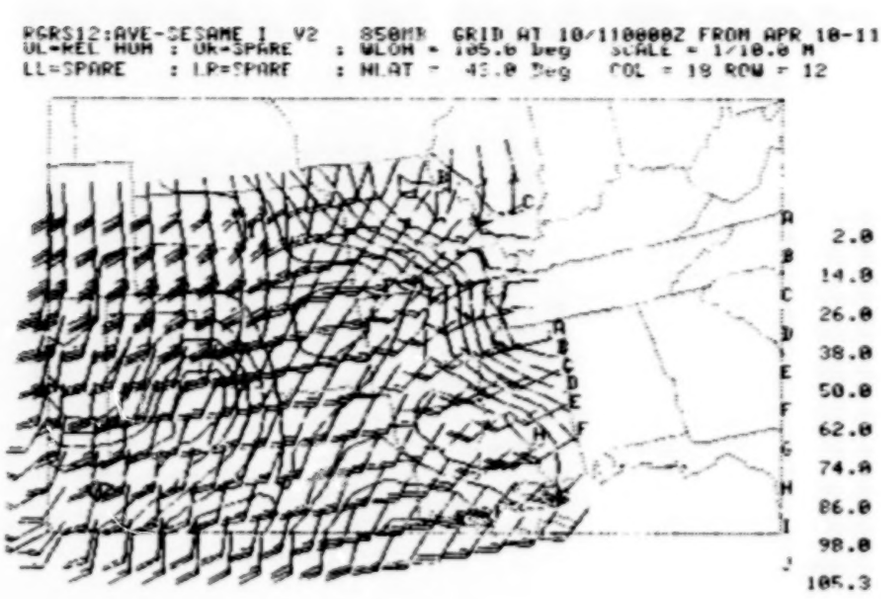
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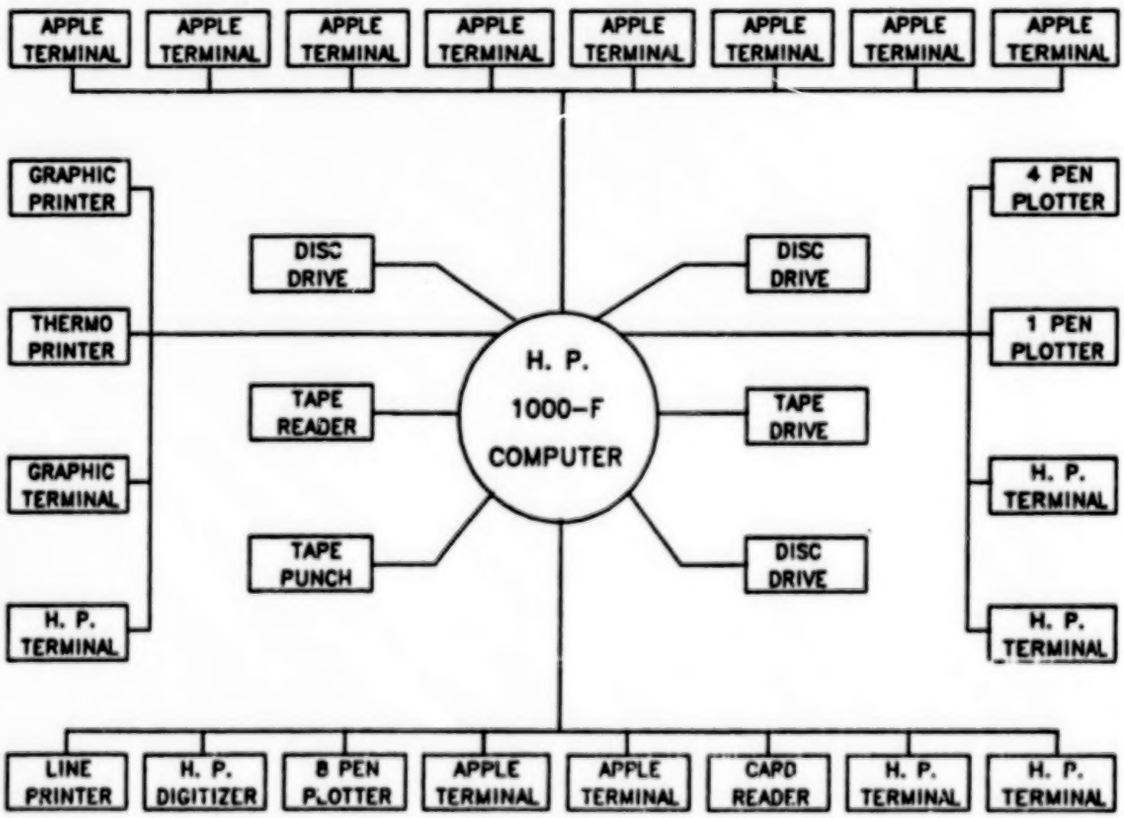

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TITLE: SEVERE STORM INITIATION AND DEVELOPMENT FROM SATELLITE INFRARED IMAGERY AND RAWINSONDE DATA

RESEARCH INVESTIGATORS:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

Available temperature, moisture and wind profiles from rawinsonde observations all over the United States were fed into the McIDAS system at the NASA/MSFC. Barnes (1964) scheme was used to maximize detail in numerical map analysis. The geographical distribution of potential temperatures, mixing ratio, and streamlines of flow patterns at 850, 700, and 500 mb heights was used to understand the prestorm convection and the horizontal convergence of moisture. From the analysis of 21 tornadoes that occurred in May, June, and August 1982, the following conclusions were reached: (1) Strong horizontal convergence of moisture appeared at the 850, 700, and 500 mb levels in the area 12 hours before the storm formation. (2) An abundantly moist atmosphere below 3 km (700 mb) became convectively unstable during the time period between 12 and 24 hours before the initiation of the severe storms. (3) Strong winds veering with height with direction parallel to the movement of a dryline, surface fronts, etc. (4) During a 36-hour period, a tropopause height in the areas of interest was lowest at the time of tornadic cloud formation. (5) A train of gravity waves was detected before and during the cloud formation period.

Rapid-scan infrared imagery provided near real-time information on the life cycle of the storm which can be summarized as follows: (1) Enhanced convection produced an overshooting cloud top penetrating above the tropopause, with cloud top temperatures 4 to 9°C below the temperature of the tropopause, making the mass density of the overshooting cloud much greater than the mass density of the surrounding air. (2) The overshooting cloud top collapsed at the end of the mature stage of the cloud development. (3) The tornado touchdown followed the collapse of the overshooting cloud top.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Study of the prestorm environment is the major focus of our current research activities. Available rawinsonde data are analyzed to determine the geographical distribution of potential temperatures, mixing ratio, and winds at heights from the ground to the upper troposphere. The purpose of study is to investigate the mechanisms responsible for the initiation of convection and the horizontal convergence of moisture.

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The difference between the overshooting cloud-top height and the tropopause height is important in the development of severe storms. The collapsing rate of the overshooting turret is proportional to the volume of the cloud top above the tropopause and the temperature differential. The difference between the overshooting cloud-top height and the tropopause height may increase if the tropopause height decreases during the time period of the storm formation. The local tropopause height can possibly be modified by heating from sources in the stratosphere and/or the troposphere. There is a mutual interaction between the variation of the tropopause height and the latent heat released from the condensation of moisture and cloud formation, and also the interaction of pronounced fronts. Our current focus of research is to investigate these mutual interactions and their affect on the storm formation.

PLANS FOR FY-85:

In addition to the mutual interaction between the variation of the tropopause height and the heating from the troposphere due to the latent heat released from the moisture condensation and cloud formation, heating also can occur from the stratosphere due to the absorption of ultraviolet radiation and the releasing of infrared radiation during the conversion of oxygen to ozone. In the plans for the FY-85, the vertical profiles of ozone and the total ozone data will be investigated and compared with tropopause variations.

Not only is lightning linked to storm dynamics in the highly convective spring and summer thunderstorms, but it is also related to the dynamics in weaker winter storms. We will study the relationship between the lightning activity and the storm characteristics, such as cloud heights, growth/collapse rates of cloud tops, cloud top temperatures, etc., observed on rapid-scan imagery obtained from satellites.

RECOMMENDATIONS FOR NEW RESEARCH:

It is recommended that ozone and VAS data be added to the combination of weather maps, radar summaries, rawinsonde data, lightning observations, and rapid-scan satellite imagery used in studying the environment favorable for severe storm formation and development.

LIST OF PUBLICATIONS PREPARED SINCE JUNE 1983:

1. Hung, R. J., Dodge, J. C., and Smith, R. E., The life cycle of a tornadic cloud as seen from a geosynchronous satellite, AIAA J., 21, 1217-1224, 1983.

2. Hung, R. J., and Smith, R. E., Remote sensing of Arkansas tornadoes on April 11, 1976 from a satellite, a balloon, and an ionospheric sounder array, Int. J. Remote Sensing, 4, 617-630, 1983.

3. Hung, R. J., and Smith, R. E., Case study of the March 24, 1976 Elton, Louisiana tornado using a satellite infrared imagery, Doppler sounder, rawinsonde and radar observations, Int. J. Infrared and Millimeter Waves, 4, 375-400, 1983.

4. Hung, R. J., and Smith, R. E., Computer image processing of up-draft flow motion and severe storm formation from satellite, Flow Visualization, 3, 173-180, 1983.

5. Hung, R. J., and Smith, R. E., Overshooting cloud-top penetrated above the tropopause and the severe storm formation, Trans. Am. Geophys. Union, 64, 201, 1983.

6. Hung, R. J., and Smith, R. E., Remote sensing of severe storms over the Tibet-Tsinghai Plateau, Int. Sympo. on Remote Sensing of Environt., pp. 104, ERIM, Ann Arbor, Mich., 1983.

7. Hung, R. J., Liu, J. M., Tsao, D. Y., and Smith, R. E., Satellite remote sensing of convective clouds and precipitation over the Xizang Plateau of China, Univ. of Alabama in Huntsville Res. Rept. No. 390, pp. 50, 1984.

8. Hung, R. J., and Smith, R. E., Overshooting cloud tops, variation of tropopause and severe storm formation, Conf. on Satellite Meteorol./ Remote Sensing and Appl., ed., by J. Theon, AMS, Boston, Mass., 1984

9. Hung, R. J., and Smith, R. E., Visualization of convective flow patterns from infrared imagery analysis, Southeastern Conf. on Theoret. and Appl. Mech., 12, in press, 1984.

10. Hung, R. J., Liu, J. M., Tsao, D. Y., and Smith, R. E., Relationship between convective clouds and precipitation over Qinghai-Xizang Plateau area from satellite remote sensing and groundbased observations, Int. J. Remote Sensing, 5, in press, 1984.

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TITLE: Mesoscale Analysis of VAS 6.7μm Image Data for Several Case Studies

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS:

Moisture imagery from the 6.7μm water vapor channel on VAS has been available to scientists in the last few years on a somewhat regular basis. Normally this information is just one of twelve channels used in produceing temperature and moisture profiles via various inversion techniques. Recent studies have also used this moisture measurement to produce mean layer relative humidity and precipitable water values for the layer in which the radiation is emitted and also to diagnose regions of the atmosphere which are potentially unstable. Few attempts have been made, however, to verifiy the information content (moisture) of these images mainly due to the lack of appropriate ground truth data. Verification efforts documented in this report use special mesoscale rawinsonde moisture measurements from the AVE/VAS field experiment.

Several case studies have been examined in an attempt to relate VAS water vapor channel radiance data to atmospheric moisture. Since the 6.7μm channel detects radiation emitted by atmospheric water vapor from a rather thick layer, a scheme was developed which weighted rawinsonde observations of relative humidity in a similar manner. A comparison of the two fields (weighted relative humidity values from gridded rawinsonde observations and the VAS water vapor image) indicated that even when mesoscale data were used, the technique only presented a smooth representation of the radiance field. This probably occured for several reasons. First, the satellite image displays significant variability down to individual pixels (16km on a side) which is very much sub-grid-scale to the rawinsonde measurements. Second, since the level of the moisture from which the radiation is emitted is unknown, the weighting function for the VAS channel (and therefore the weighting formulation applied to the rawinsonde measurements) must be approximated. This weighting function is dependent on both the temperature and moisture distribution of the atmosphere.

In order to avoid the weighting function problem mentioned above, cross sections of relative humidity from the mesoscale rawinsondes were produced which sliced the water vapor imagery in particularly interesting regions (areas of high and low blackbody temperatures). Comparisons were then made between the cross sections and the variations in the VAS radiance data along the cross section line. This approach was more fruitful in determining

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that bright regions in the water vopor imagery (cold blackbody temperatures) were often associated with thin layers of high relative humidity or thick layers of only moderately moist air. The reverse was also found to apply, i.e., dark regions (warm blackbody temperatures) in the imagery corresponded well with very dry regions in the cross sections. These relationships are not always clear-cut or easy to distinguish however, and in a few cases the bright regions did not correspond to moisture deduced from the rawinsonde cross sections. It is hypothesized, however, that in some instances the radiation field (water vapor image) can reflect the temperature along an isosteric surface on the cyclonic side of a propagating jet streak (Ramond, et al., 1981).

CURRENT AND FUTURE WORK:

One area which is currently being investigated is the extent to which low level moisture can be detected by the 6.7μm water vapor channel. It is believed that under certain conditions where the middle and upper troposphere is extremely dry, radiation emitted from water vapor below 700mb can be detected with this channel. If this is the case it adds another complexity in that this channel has an even wider range than previously thought. Further investigations will also address the effect of temperature on the variations in this water vapor channel.

PUBLICATIONS SINCE JUNE 1983:

1. Mesoscale analysis of 6.7μm image data from the VISSR Atmospheric Sounder (VAS) for several case studies. NASA TM, in press, NASA Marshall Space Flight Center, Huntsville, Alabama, 1984.

2. Mesoscale analysis of 6.7μm image data from the VISSR Atmospheric Sounder (VAS) for several case studies. Preprints Satellite Meteorology/ Remote Sensing and Applications Conference, AMS, Boston, June 1984, in press.

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Ramond, D., Corbin, M. Desbous, G. Szejwach, and P. Waldteufel, 1981: The dynamics of polar jet streaks as depicted by the METEOSAT WV channel radiance field. Mon. Wea. Rev., 109, 2164-2176.

N84
34874

UNCLAS

TITLE: An Application of VISSR Atmospheric Sounder (VAS) Data in Mesoscale Analysis

N84 34874

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS:

This research topic is an off-shoot of a study which evaluated the accuracy and representativeness of VAS sounding data with special rawinsonde measurements (discussed elsewhere in this document). General findings of the study concluded that significant discrepancies often occur between VAS sounding and rawinsonde data at the mesoscale. These discrepancies usually represent biases in the satellite soundings which occur because of the poor vertical resolution of VAS especially where significant temperature and moisture fluctuations (inversions) occur. The influence of these biases on the horizontal representation of the atmosphere by VAS usually results in reduced horizontal gradients but often possesses significant mesoscale structure which could be quite useful in diagnostic studies and nowcasting. There are other problems with satellite sounding data other than errors and biases which limit the usefulness of the data, however. Irregular data spacing (due to clouds) often presents a major problem in using VAS data and restricts a detailed mesoscale analysis to a small area. Ordinary attempts to get mesoscale detail with VAS over a large area often result in over-smoothed fields in order to avoid spurious results in data sparse regions. A solution to this problem is to perform a complicated assimilation scheme to combine VAS and rawinsonde data to produce a regional analysis of the atmosphere. This involves considerable effort, does not totally address the satellite-rawinsonde bias problem, may over-smooth the data, and is not very applicable to diagnostic studies. The research highlighted in this write-up presents a very simple and straight forward approach to these problems to produce mesoscale analyses of VAS data over a large area (which may contain cloudy regions) with good temporal and spatial consistency.

Commonly used objective analysis schemes are very effective in producing gridded fields of meteorological parameters where data spacing is uniformly spread over the entire analysis region. The amount of detail contained in these fields can be controlled to produce consisted mesoscale analyses. A scheme similar to Barnes (1973) is employed in this study to produce gridded analyses of basic and derived parameters of satellite data over a 2000 x 1500 km region in the central part of the United States. The general procedure in the Barnes scheme is to apply a correction pass to an initial gridded field where the correction at each grid point is based on the data values and their distance from each grid location. Mathematically this can be expressed as follows:

$$G_{i,j} = I_{i,j} + \frac{\sum_{k=1}^{N} (X_k - XI_k) \cdot W_k'}{\sum_{k=1}^{N} W_k'} \qquad (1)$$

where,
G is the final grid point value,
I is the grid value from the initial pass,
X is an observation,

XI an initial pass grid point value interpolated to an observation,
i x coordinate increment,
j y coordinate increment,
N the total number of observations, and
W´ the weight factor given by

$$\exp\left(\frac{-(D)^2}{\gamma \cdot 4c}\right)$$

with
D being the distance between the grid point and the observation.

This scheme will produce very nice results on uniformly spaced observations with judicious values of γ and 4 c.

In data sparse regions the "goodness" of the interpolated values becomes questionable since both the influence of distant data and the sum of the weight factors can be small (see (1)). This difficulty has been experienced by anyone getting "bullseyes" or "irregularities" in their gridded fields. Reducing the sum of the weights of the observations (denominator of (1)) in data sparse regions, as in this study, increases the influence of the first pass on the final field and produces a somewhat smoother (depending on the information content of the first pass) but consistent analysis in these areas. Mathematically, this modification is accomplished with a slight change to the denominator of (1) above as follows:

$$G_{i,j} + I_{i,j} + \frac{\sum_{k=1}^{N}(X_k - XI_k) \cdot W_k'}{(\sum_{k=1}^{N} W_k') + ifl} \qquad (2)$$

The value assigned to "ifl" is somewhat arbitrary and depends on the selected γ , 4c value, and on the data density. A general guideline obtained from experience is to pick "ifl' such that in data rich areas 'ifl' is much less than the sum of the weights and in data sparse regions 'ifl' should be greater than or equal to the sum of the weights. In addition to this modification, the first pass gridded field usually produced by the Barnes scheme was substituted with the first guess field used in the actual retrieval of the satellite temperature and moisture profiles (in this case, an LFM forecast field). The effect of using these changes in the scheme is the generation of a consitent field in data void regions. Near the edge of data sparse regions, the analysis procedure produces a nice blend of the initial pass (first guess) and the satellite soundings which is consistent with the data trends. In regions of dense satellite soundings, the scheme does not significantly alter the sum of the weights normally assigned and produces a conventional product. Use of this first guess is also appropriate since the final retrieved VAS soundings are not totally independent from their first guess (Smith, 1983).

Figure 1a displays a subjective hand analysis of 700 mb satellite derived temperatures at 2035 GMT and the corresponding ground truth rawinsonde observations are in Fig. 1b. Several major items are apparent from looking at these figures. First, dense areas of satellite soundings are available over limited regions. A large data gap exists over east Texas, Arkansas, and Missouri where clouds prohibit accurate retrievals and thinly spaced observations are present over Colorado. Several pockets of cold temperatures exist over northern Kansas, west Texas and along the Big Bend region. A very small pocket of warmer exists over eastern New Mexico. This latter feature is quite small and mainly due to one satellite sounding. The ground truth

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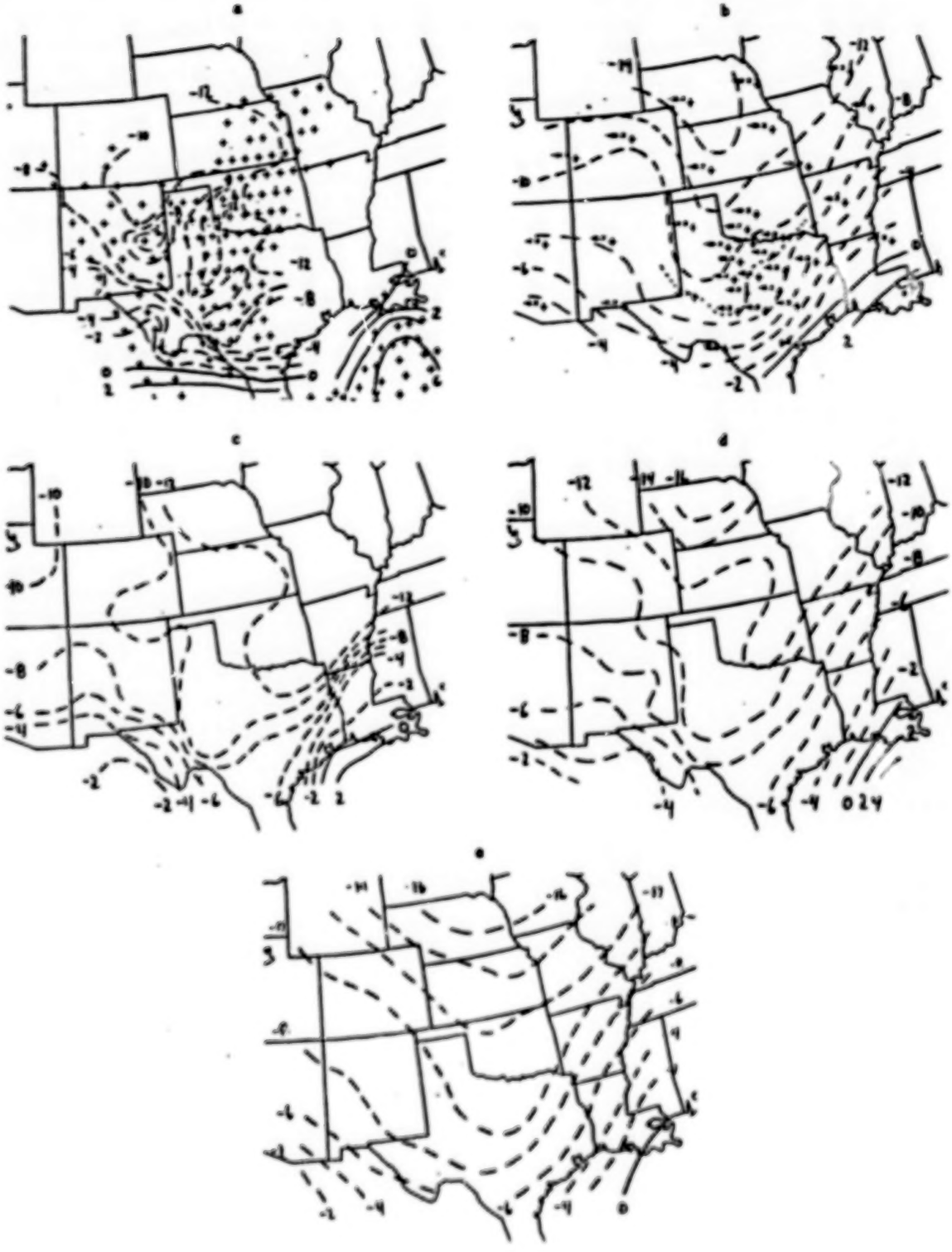

Figure 1. Subjective manual analysis of 700mb temperatures at 2045 GMT 6 March 1982 for VAS (a) and rawinsonde (b) data sets. Conventional two-pass objective analysis of VAS data (c), and the modified scheme gridded temperature field (d) produced substituting a LFM forecast field (e) for the first pass. Temperatures are in degrees C.

rawinsonde data indicate actual environment conditions over the region. The coldest air is centered over Nebraska and Kansas with a thermal trough extending down through west Texas. A ridge of warm air exists in Colorado and New Mexico.

Figure 1c indicates the type of product available over the region with the conventional application of the analysis scheme. In areas where data density is adequate, the satellite soundings are well analyzed, however, in data sparse regions the contours are bunched and/or disorganized. At the eastern edge of the large data void, a somewhat artificial and misleading cold trough is present. This is due to the scheme and also the trend of the data where cloud-contaminated retrievals produce a cold bias. Figure 1d shows the analyzed satellite data when the modified scheme is employed. The LFM first guess data grid which the scheme utilizes is shown in Fig. 1e. This scheme produces a much more realistic analysis in data void regions while maintaining the integrity of the analysis in other areas. The small warm pocket over New Mexico has been modified and the artificial cold trough in the cloudy areas has been removed. The cold trough extending back into west Texas is still present and is one of the dominant features in the satellite and rawinsonde analysis. The application of this scheme at all time periods has produced a consistent satellite data set with considerable mesoscale detail.

CURRENT AND FUTURE WORK:

Current efforts involve refining the technique and testing its performance on several other case studies. Although the scheme is very simple to apply, a judicious choice of the first guess and its influence is essential for a good analysis. Further studies of these restrictions on the data fields are necessary. The application of this scheme to satellite soundings other than those produced by a physical retrieval method should be evaluated to determine the broader use of this procedure.

PUBLICATIONS SINCE JUNE 1983:

1. Application of VISSR Atmospheric Sounder (VAS) Data. NASA Technical Memorandum (in press), Marshall Space Flight Center, Huntsville, 1984.
2. Application of VISSR Atmospheric Sounder (VAS) Data in Weather Analysis. Preprints 10th Conf. on Weather Forecasting and Analysis, AMS, Boston, June 1984 (in press).

References

Barnes, S.L., 1973: Objective map analysis using weighted time-series observations. NOAA Tech Memo., ERL NSSL-62, Norman, 60pp.

Smith, W.L., 1983: The retrieval of atmospheric profiles from VAS geostationary radiance observations. J. Atmos. Sci., 40, 2025-2035.

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MESOSCALE AGEOSTROPHIC CIRCULATIONS ASSOCIATED WITH BAROCLINIC JET STREAKS

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Significant Accomplishments

In our focus on studies of ageostrophic motion attending jet streaks and convection, various types of dynamical experiments have been carried out with the hybrid isentropic-sigma coordinate model during the past year. These involved examination of the effects of vorticity and static stability distributions on the intensity of secondary circulations forced by inertial accelerations as well as the superposition of an amplifying baroclinic wave on the jet streak structure.

In one series of experiments, the horizontal wind shear of the jet streak was increased relative to previous experiments (Fig. 1) while retaining the same maximum wind speed and alongstream variation in the wind. The result was an enhanced development of the direct and indirect circulations at the jet entrance and exit regions, respectively, as revealed by increased precipitation in the jet's left exit region. From quasi-geostrophic concepts, the increase in positive differential vorticity advection enhanced the vertical motion and increased the precipitation. The increase in positive vorticity advection was associated with the larger positive vorticity on the jet's cyclonic side. Another test was made in which the initial anticyclonic wind shear was increased only on the jet's anticyclonic side (reducing the absolute vorticity from 4×10^{-5} to 1.5×10^{-5} s^{-1}) but was not increased on the cyclonic side. In this case, the positive differential vorticity advection was not increased. Figure 2 shows that precipitation was still 50% greater under the jet's left exit region than for the original experiment. In this case, the increased ageostrophic response of the baroclinic jet streak must be explained using Eliassen's concepts in the sense that a decrease in the absolute vorticity results in an enhanced response of the indirect circulation at the jet exit. This in turn leads to greater upward motion on the cyclonic side and thus to increased precipitation.

Another experiment involved decreasing the static stability below the jet streak while maintaining essentially the same velocity structure. This was accomplished by increasing the ground temperature by 10 K along the center of the channel and increasing the lapse rate from 5×10^{-3} K/m to 6×10^{-3} K/m. Areas of precipitation formed under the right entrance and left exit regions with magnitudes three to four times larger than for the original experiment.

The third major experiment involved the superposition of an amplifying baroclinic wave on the jet streak. The maximum wind and alongstream variation of the jet streak at 340 K were nearly the same as in the zonal experiments. The small circular surface low pressure center (997 mb) was located downstream of the trough axis while the circular high pressure center (1003 mb) was located upstream. Figure 3A shows the surface pressure and temperature configurations at 36 hours. Note the apparent development of cold and warm frontal regions south and east of the low. The development of a relatively continuous band of precipitation along the baroclinic zone is shown in

Figure 3B. Areas of maximum rainfall tend to coincide with the areas of greatest positive thermal advection.

A comparison was made between experiments with similar pseudo-geostrophic and geostrophic initial wind distributions. Subsequent evolution of the ageostrophic wind may be assessed by decomposing the ageostrophic acceleration into terms describing centripetal acceleration, kinetic energy gradient, and non-steadiness. The latter effect is, of course, given by $\partial \bar{U}/\partial t$. Figure 4 depicts this acceleration at 6 hours into the simulations for both the pseudo-geostrophic and geostrophic experiments. The general sense of the vector field in the pseudo-geostrophic case (towards higher pressure) is the same as that which occurs at later time periods in both runs after the imbalances of initialization have subsided. However, in the geostrophic case the acceleration downstream of the wind maximum at 6 hours is almost reversed in direction (towards lower pressure). The cross product of $\bar{k}$ with $\partial \bar{U}/\partial t$ gives the direction of the ageostrophic motion. In the geostrophic case at 6 hours, the ageostrophic motion in this area is almost entirely reversed from the field that ultimately develops. Pseudo-geostrophic initialization has eliminated the unrealistic adjustment of the geostrophic case.

Focus of Current Research

The current emphasis of effort is on consolidation of the experimental model results involving the attributes of pseudo-geostrophic initialization of baroclinic jets and several studies of the effects of horizontal wind shear, static stability, and amplifying baroclinic circulations on ageostrophic motion associated with jet streaks. The influence of viscosity and horizontal resolution is also being analyzed.

Recommendations for New Research

Future work should investigate the strengths and weaknesses of:

1) Determination of atmospheric structure from conventional and satellite observations using a time-dependent isentropic assimilation model.
2) Tests of numerical mesoscale prediction comparing different methods of data assimilation.
3) Isentropic models for numerical weather prediction.

Publications Since June 1983

Black, T. L., 1984: An investigation of ageostrophic circulations of jet streaks using a hybrid isentropic-sigma coordinate numerical model. Ph.D. thesis, University of Wisconsin.

Johnson, D. R., 1984: The inducement of planetary boundary layer mass convergence associated with varying vorticity beneath tropospheric wind maximum. Proc. 2nd Int. Symp. on Nowcasting, Norrkoping, Sweden (to be available from Eur. Space Agency, Sci. and Tech. Publ. Branch).

Keyser, D. A. and D. R. Johnson, 1984: Effects of diabatic heating on the ageostrophic circulation of an upper tropospheric jet streak. Conditionally accepted for publication in Mon. Wea. Rev.

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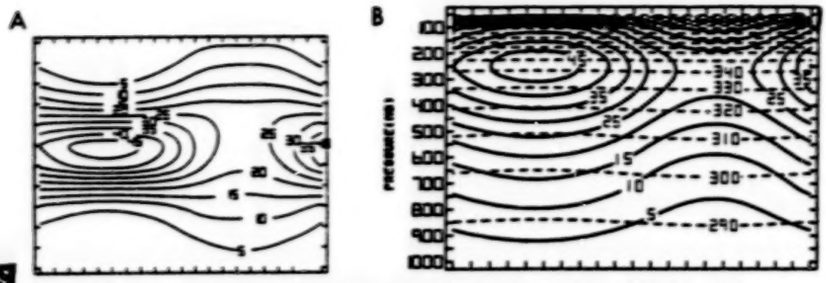

Figure 1. Initial pseudo-geostrophic wind field for zonal jet; solid lines are isotachs (m/s). (A) Horizontal cross section at 340 K; (B) vertical west-east cross section through center of domain; dashed lines are isentropes (K).

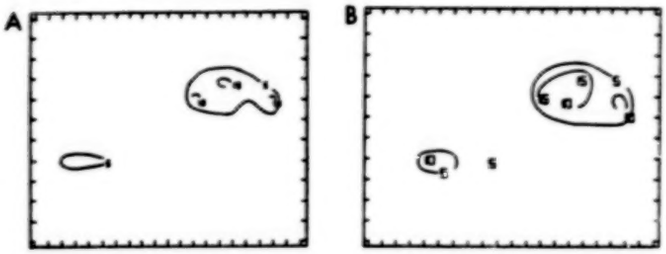

Figure 2. Total precipitation (10^{-1} mm) for run with zonal jet. Initial minimum absolute vorticity south of jet is (A) 4×10^{-5} s^{-1}, (B) 1.5×10^{-5} s^{-1}.

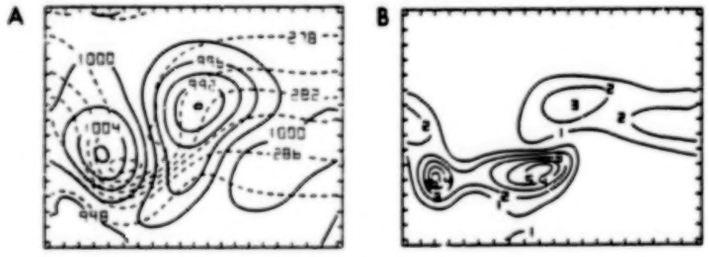

Figure 3. Surface conditions at 36 hours for run initialized with wave structure and circular pressure centers. (A) Solid lines are isobars (mb) and dashed lines are temperature (K), (B) total precipitation (mm).

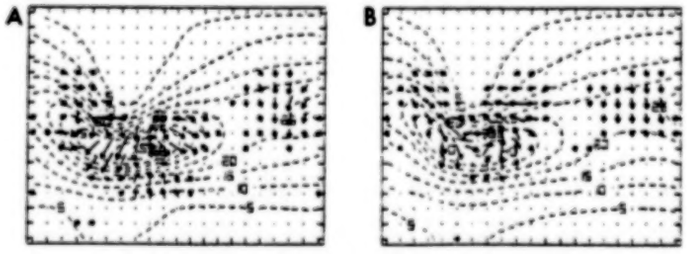

Figure 4. Vectors describing direction and relative magnitude of $\partial U/\partial t$ at 6 hours at 340 K. Dashed lines are isotachs (m/s). (A) Pseudo-geostrophic initialization, (B) geostrophic initialization.

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N84 34876

TITLE: Numerical Simulation of Mesoscale Precipitation

RESEARCH INVESTIGATOR:

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Atmospheric Sciences Division
NASA/ MSFC Alabama 35812 (205) 453-5532

SIGNIFICANT ACCOMPLISHMENTS FY-83:

1. The NCAR graphics system has been implemented on the ASD Perkin-Elmer 3250 computer. User friendly subroutines have been written to allow easy access to mapping, contouring and vector plotting routines without prior knowledge of NCAR graphics.
2. Software for initializing the LAMPS mesoscale model has been written and implemented with options for real, real non-divergent or balanced initial winds. The objective analysis has been modified to use LFM or Global model data as first guess fields and to accept radiosonde or satellite data as processed and archived on MSFC/ ASD or University of Wisconsin formatted tapes.
3. The LAMPS model code has been implemented on the ASD Perkin-Elmer; several short test forecasts have been made for the March 6 1982 and April 25, 1975 cases.
4. A version of the LAMPS map processing graphics module was successfully run on both the Perkin-Elmer and IBM 4341. A simpler program was written which allows for a quick look at model output fields (also using NCAR graphics) and for transfer of gridded data from the Perkin-Elmer to the HP-1000.

CURRENT FOCUS OF RESEARCH:

1. Development of methods to incorporate VAS satellite derived specific humidity and precipitable water absolute values and/or gradient information into mesoscale model initial states.
2. Work is continuing on testing of the basic LAMPS model code, and specifically on inclusion of the convective parameterization.
3. A simplified version of the LAMPS "wind adjustment" program has been written and is being tested for inclusion with the MSFC model initialization package. Work has just begun to similarly modify another LAMPS routine to generate model time dependent lateral boundary tendencies.
4. Work is in progress to convert the LAMPS map processing code on the ASD Perkin-Elmer into an interactive program for more flexible viewing of mesoscale model output.
5. Work is underway to implement the LAMPS model code on the NASA/ GSFC CYBER 205 computer for remote execution of large production model runs from MSFC.

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FUTURE RESEARCH:

The remainder of FY-84 will be spent in support of items listed under current research. For FY-85 plans have been made for model forecast impact studies using satellite derived moisture. March 6, April 24 and April 26 cases have been chosen for study because of the availability of VAS measurements. Verification will emphasize mesoscale precipitation forecasts. These studies will provide evaluation for the quality of satellite moisture fields, model sensitivity to mesoscale moisture structure, and will provide guidelines for future space sensor requirements as regards the observation of atmospheric moisture.

PUBLICATIONS:

Results from a limited area mesoscale numerical forecast, Part I: Initialization with SESAME-AVE radiosonde data. (Submitted to Monthly Weather Review).

Results from a limited area mesoscale numerical forecast, Part II: Radiosonde versus satellite data initialization. (In preparation)

Initialization of a mesoscale model for April 10, 1979 using alternative data sources. (Submitted for publication as a NASA technical document).

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STUDIES OF MIDLATITUDE CYCLONE STRUCTURE WITH SEASAT SCANNING MULTICHANNEL MICROWAVE RADIOMETER

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In this project we use the new tools provided by the atmospheric water channels of Seasat's Scanning Multichannel Microwave Radiometer (SMMR) to investigate mesoscale structure at various stages of the development of a midlatitude cyclone. Seasonal and graphic differences in the storms are also studied.

Significant Accomplishments

This is a new grant, only in effect for six months. However, the work follows our previous studies of North Pacific Cyclones which occurred during September 1978 and benefits from our available software and experience with the SMMR data.

There have been two significant accomplishments to date:

1) We have begun to analyze several cyclones as they cross the Gulf Stream during September 1978. We have paid special attention to the infamous "QEII" storm, which caused trouble for the ocean liner Queen Elizabeth II. We note that substantial amounts of water vapor are present in the warm air over the Gulf Stream. Cold fronts are well defined by the gradients in integrated atmospheric water vapor, and interesting differences in the water vapor content exist between regions which have the same rain rates.

2) We have combined SMMR and SASS (Seasat A Satellite Scatterometer) data at its highest resolution, 50 km, to study mesoscale regions of convergence and divergence, and waves on frontal boundaries between the cold and warm air.

Focus of Current Research

We are currently doing the following:

1) We are looking for differences between the late summer cyclones in the North Pacific and North Atlantic.

2) We are beginning to analyze the relationship between low level convergence, available from SASS, and total atmospheric water vapor, liquid water and rain rate, available from SMMR, trying to determine what it can tell us about the dynamics of the storm. For this we are considering the severity of assumptions one must make about steady state, horizontal and vertical advection and continuity or discontinuity in the vertical.

3) We are evaluating the forecasting value of the detection of waves on the cold front of a mature cyclone with SMMR data.

Plans for FY 85

1) As we amass more case studies we look for statistically valid evidence of differences in cyclone moisture content between the North Pacific east coast and the Western Alantic.

2) Next we plan to analyze cyclones in the Southern Hemisphere during Seasat's time, especially to see whether the moisture in the winter storms show the same clear relationship to the surface cold front as we have seen for the late summer storms in the Northern Hemisphere.

3) We are generally aiming to be more sophisticated in the use of combined Seasat SASS and SMMR data.

4) Together with our colleague Frank Wentz of Remote Sensing Systems, we plan to analyze the rain rate information from SMMR on the smallest pixel scale, 0 (12 km), rather than the 50 km now provided. This is important since rain occurs on this scale or smaller and rain drop effects on microwave brightness temperatures are highly non-linear.

Recommendations for New Research

Further work demonstrating the diagnostic value of the atmospheric water parameters: integrated water vapor, total cloud liquid water and rain rate for midlatitude cyclones should be carried out. I feel that these kinds of data can have important operational applications, especially in view of the next microwave radiometer's much larger swath width. (The next microwave radiometer scheduled for launch is the Special Sensor Microwave Imager, SSM/I, which will be on a Defense Department satellite in 1986. It will have 1300 km swath width compared to Seasat SMMR's 600 km.) It is also my opinion that the total cloud liquid water and rainrate information should be used in prognostic models. We have previously not had such data available, and its kind does not, therefore, have immediate use. However, we know that clouds and rain are related to latent heat release and heating and cooling of atmospheric layers by visible and infrared radiation. After further verification of the algorithms for these parameters, we should be able to use them to initialize and update numerical models. Better verification can only come with new instruments. In the meantime we can study the consequences of such information with the present data from SMMR.

List of Publications Prepared Since June 1983:

Katsaros, K. B. and L. A. McMurdie, 1983: Atmospheric moisture as vapor and liquid in storms seen with microwave radiometry. Presentation at 18th General Assembly of IUGG, Aug., 1983, Hamburg, W. Germany.

Katsaros, K. B. and L. A. McMurdie, 1983: Atmospheric water distribution in cyclones as seen with Scanning Multichannel Microwave Radiometers (SMMR). Presentation at IGARSS'83, Sept., 1983, San Francisco, Calif.

McMurdie, L. A., 1983: Seasat Scanning Multichannel Microwave Radiometer (SMMR) Observation of North Pacific Cyclones. M.S. Thesis, Dept. of Atmospheric Sciences, Univ. of Washington, Seattle, Wa, 205 pp.

McMurdie, L. A. and K. B. Katsaros, 1984: Atmospheric water distribution in a midlatitude cyclone observed by the Seasat Scanning Multichannel Microwave Radiometer. Mon. Wea. Rev. (submitted).

N84
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N84 34878

TITLE: Statistical Severe Storm Nowcasting Comparison of VAS and Rawinsonde Soundings

RESEARCH INVESTIGATOR:

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SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

The author's statistical severe storm nowcasting technique using upper air soundings (VAS or radiosonde) has been translated to the IBM McIdas system. This is a significant change from the older Harris /6 McIdas computer system. VAS sounding data processed at the NESS Developement Laboratory at the University of Wisconsin (on the IBM McIdas system) are sent nearly in real time to Kansas City NESS/SFSS personel, along with the author's product, the probability of severe storms. Kansas City personel are thus able to compare the severe storm information content of VAS and rawinsonde sounding data. A sample is shown in figure 1, where the contours of the likelihood of severe storms based only upon upper air VAS and rawinsonde data are shown, as well as the SELS outlook based upon surface data, radar, operational computer models, and other data sources.

FOCUS OF CURRENT RESEARCH:

The true strengths and weaknesses of satellite sounding data are becoming apparent with these frequent nowcasting comparisons. The impact of data gaps due to clouds has become clear in several cases this spring. The ability of the VAS soundings to illustrate features not always seen by the rawinsonde network has also become clear. For example, in figure 1 the VAS contours closely follow the warm sector in the Gulf Coast states, whereas the rawinsonde-based contours apparently do not see this verified feature in the same way.

RECOMMENDATIONS FOR NEW RESEARCH:

Though this is not a new idea, case studies seen so far strongly show the need for efforts to combine satellite and rawinsonde products. Even though the VAS data by itself appears to have statistically as much severe storm information as radiosonde data, differences (both shortcomings and advantages!) of each data type are readily apparent. The VAS sounding data being available after the 12Z radiosonde data undoubtedly influenced the case in the figure. VAS sounding data gaps due to clouds have hurt the ability of this nowcasting technique in several cases, even though the existing data agreed very well with the radiosonde network.

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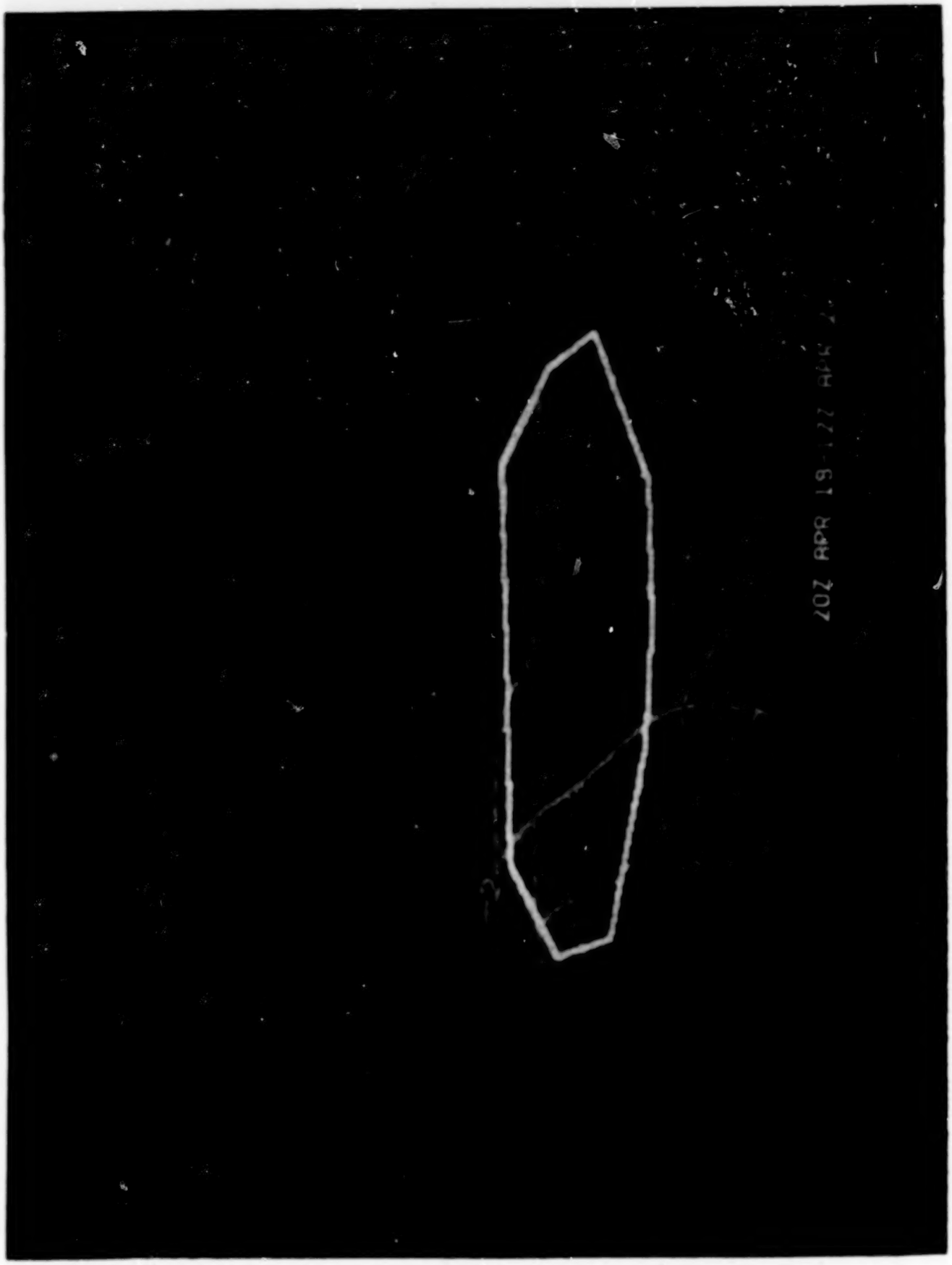

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N84 34879

TITLE: Cloud Scale Influences on Mesoscale Precipitation Patterns

RESEARCH INVESTIGATORS: Fred J. Kopp
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G. D. Emmitt (USRA)
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SIGNIFICANT ACCOMPLISHMENTS FY84:

While a summer '83 visitor to the Marshall Space Flight Center a version of the Institute of Atmospheric Sciences' cloud model was brought up on the NASA computers. The model is a two dimensional, time dependent finite diffence grid model simulating atmospheric motions, potential temperature, water vapor, cloud liquid, cloud ice, rain and small hail. The nonlinear partial differential equations which make up the model are integrated on a 19 kilometer square grid with 200 meter spacing between grid points. Lateral boundary conditions are open allowing flow in and out of the model domain. The model is presently running on the Perkin Elmer 3250 and the IBM 4341.

A number of experiments have been run on two soundings taken on April 24, 1982 at Amarillo, Texas. The first sounding is from the morning and is very stable so little convection can be expected. Varing amounts of convergence are simulated to test the effects on cloud initiation and development. The second sounding taken three hours later at 1700Z is much warmer at the surface and much less stable. Runs made tested the effects of convergence on the convection; one case with divergence in the lower atmosphere was run.

The early morning sounding needed a convergence value of 10^{-4} per second before a cloud formed. The cloud became quite active during the simulation producing precipitation. Analysis of the results showed that the sounding changed during the simulation due to the convergence as well as diffusion effects. Results from the second sounding are more interesting. With this more unstable sounding, a cloud forms readily with no convergence. After a simulation of about 1.5 hours the cloud has formed precipitation and dissipated. With divergence of 2×10^{-5} a cloud forms but quickly dissipates with no precipitation falling to the ground. Convergence enhances the amount of precipitation in this case and the dynamics as well. The cloud is broader and the precipitation falls over a wider area.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

During the summer of '84, more realistic convergence/divergence values will be taken from a mesoscale model which is being run to simulate the mesoscale dynamics on April 24, 1982. These more realistic values should result in a better simulation from the cloud model. Time varying values of convergence can be simulated to produce more realistic cloud dynamics. Graphics for the model will be brought up on the Perkin Elmer and hopefully the FR80. Comparisons with available observations will be made.

PLANS FOR FISCAL '85:

Additional cases could be run and quantitative predictions made of precipitation production under varying amounts of dynamic forcing. Eventually, near real time estimates of precipitation could be attempted using combined mesoscale and cloud scale models.

PUBLICATIONS:

Cloud Scale Influences on Mesoscale Precipitation Patterns. Report to NASA, 1983, 23p.

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TITLE: Morphology and development of organized convection in the boundary layer

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SIGNIFICANT ACCOMPLISHMENTS, FY-84

Further progress has been made in the analysis of the data obtained during the FY-81 flight program. That program produced vector windspeed measurements in a horizontal plane derived from an airborne Doppler lidar. Gradual improvement in the understanding of the various error sources in the measurements has allowed error correction to the point where continuity in the scalar measurements is measured in tenths of 1 m/s in the boundary layer. The systematic errors which remain do not affect local flow analysis.

The removal of much of the short-term error in the data fields has produced dramatic measurements of wave structures in and near the boundary layer. Deep boundary layer measurements in CCOPE (to 3000 m altitude) show pronounced interacting wave structures with periods on the order of 2 km. Observations of similar waves in California at altitudes down to 300 m demonstrate that the lidar system is sufficiently stable to detect structures with amplitudes of only 1 m/s. Wave structures have also been observed to result from obstacle flow.

FOCUS OF FY-85 RESEARCH:

These clear-air measurements demonstrate the potential of the system for the measurement of complex structures, and are of considerable meteorological interest. The lidar system is uniquely capable of such measurements: sensitive microwave radars are capable of clear-air measurements to a certain extent, but clutter and a large averaging volume are limiting factors. However, the lidar system has been limited to scanning in a single horizontal plane. Current work will change the lidar scan pattern to allow essentially simultaneous data acquisition from several different measurement planes. This will allow 3-dimensional data to be obtained, and will provide the vertical context necessary for interpretation of wave structures. This scan pattern will produce horizontal flow fields at several altitudes throughout the boundary layer, and will allow observation of convection from the surface upward.

RECOMMENDATIONS FOR FUTURE RESEARCH:

Since high vertical resolution and vertical context are so important in boundary-layer studies, the three-dimensional capability of the system should be fully exploited during the coming flight tests.

PUBLICATIONS IN FY-84:

Boundary layer observations with an airborne Doppler lidar, 21st Conference on Radar Meteorology, American Meteorological Society, Sept. 1983

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N84 34881

TITLE: SEARCH FOR SOLAR SIGNALS IN GOES IMAGERY
and
CLOUD CLIMATOLOGY ANALYSIS

PRINCIPAL INVESTIGATOR: RALPH J. MARKSON
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A. SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

I. GOES COMPUTER IMAGE ANALYSIS SYSTEM

Our project involves digitizing and analysing 16 mm GOES IR imagery (Northern Hemisphere--1/2 hour resolution) to identify spatial and temporal variations in the clouds which may be related to solar variability. Inherent in the investigation is a cloud climatology analysis. For diagnostic purposes we initially have been examining diurnal variations.

During the past year an Interactive Graphics Package (IGP) has been added to our Computer Image Analysis System (CIAS). The overall system now includes: (1) a 16mm analyst projector which projects an image into, (2) a G.E. video camera with a 128 X 128 charge injection device array to digitize the image, (3) a custom built interface which controls the digitized image transfers to the direct memory accesss of the PDP-11/23 computer, (4) a dual double density disk drive, (5) a Raster Technologies monitor controller, (6) a VT 103 video terminal which encases the PDP-11/23 CPU, (7) a Conrac color video monitor, (8) a Digipad 5 graphics tablet with 16 function button cursor, (9) an IDS Prism dot matrix printer, (10) and a Tektronix oscilloscope which is used for previewing pictures from the G.E. camera.

The IGP was designed by three of the personnel responsible for the hardware and software at the MCIDAS facility at the Air Force Geophysics Lab (AFGL) Hanscom Field, Bedford, Massachusetts. The software that was developed contains many features that have been quite useful in analyzing the GOES imagery One of those is the ability to display up to 4 images at a time on the Conrac monitor. The 4 images may be viewed simultaneously or individually while zoomed to 2, 4, or 8 times their normal resolution. A single button enables the programmer to step through each picture creating a miniature movie loop effect. A rectangular cursor can be sized to any dimension and moved to any location in the monitors display area by either program control or by the 16 function button cursor and the Digipad 5 cursor tablet. The mini array can then be read back into the DEC PDP-11/23 to be analysed. The intensity level of specific pixels may be read quickly using a cross hair pointer controlled by the cursor and tablet. A color enhancement program enables the programmer to set up as many as 64 intervals of different colors

II. VERIFICATION OF THE SYSTEM AND INTERIMAGE NORMALIZATION

Using the current CIAS we redid our original pilot study using Western GOES data which had been done by hand. This was an analysis of overall light intensity variations in six 10 degree square boxes across the intertropical convergence zone (ITCZ) during our test period (May-July 1976). The ability to reproduce the origional analysis was a criterion that the CIAS was working properly. Initially 2 different analyses were performed on the stored data; the first

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examined the thresholded average intensity levels of each of 6 boxes in the ITCZ, the second examined the percentage of clouds greater than a threshold value in each area.

In both analyses the time of occurance of minimum intensity in boxes 1 - 6 follows local time from east to west across the Pacific. This is an important result implying that we are measuring real changes in the clouds and not artifacts arising from the preparation of the film data base or analysis procedures (which affect all areas of the image simultaneously). Anomalies occuring at 0515 and 1015 UT, apparent universal time variations, (i.e., simultaneous brightness changes in all the boxes) are probably not representative of real phenomena but arise from the way the films were produced.

Similarly, the data at times have discontinuous variations between frames. A special series of analyses were conducted to determine a method for normalizing the data. First, changes of intensity in the white border surrounding the images were studied. Intensity variations of less than 1 % were found, implying that the film was overexposed in the outer border and therefore not sensitive to the fluctuations observed in the global part of the image. Next an analysis was made of the darkest 5 % of pixels in an eastern mid-latitude area of the global image. The assumption was that at least that percentage of the area should be cloud free at all times, and therefore the intensities that are observed should be representative of the ocean (which is assumed to be at a constant temperature for periods of at least several days). Variations observed in the mid-latitude band were highly correlated with the sudden discontinuities in intensity observed in the ITCZ. The discontinuities are non-linear with intensity, i.e. the greater the intensity, the smaller the change. Using this information a curve will be determined which will normalize the light intensity variations between images. This is necessary before proceeding with additional analysis.

III. PRELIMINARY ANALYSIS OF UNNORMALIZED DATA

Preliminary correlations of the GOES images have been made between what is assumed to be the most important solar modulated parameter, the Cosmic Ray Index (CRI), as well as the Vorticity Area Index (VAI), which has been reported to vary with aspects of solar variability. Our results indicate a significant relationship between the changes in CRI to the changes in GOES intensity levels in all 6 boxes for one of the 3 test months. The high noise levels that are the result of intensity discontinuities may be responsible for the lack of similar results in the other 2 test months, or this result may be a statistical accident. Once a normalization curve has been determined and used to improve the data, the correlations will be recalculated. Needless to say, if the possible relationship between cosmic radiation and cloudiness is real, this would be of considerable significance.

Spatial and temporal autocorrelations which were performed on the GOES imagery showed decreasing correlation as the lag times increased as would be expected.

B. FOCUS OF CURRENT RESEARCH ACTIVITIES

Currently we are working on developing normalizing proceedures that will minimize the noise levels previously discussed. Once this is accomplished we will expand our data base from 3 months to 1 and then 3 years and proceed with the analyses of various measures of solar variability versus the spatial and temporal changes in clouds (particularly deep convection).

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In conjunction with Prof. Peter Stone, head of the Center for Meteorology and Physical Oceanography at MIT who has provided support for a student, we are putting the CIAS to use in a new project. This is to relate variations in ionospheric potential (from aircraft and balloon measurements) to tropical convection (as determined by the CIAS). Since this convection drives the Hadley Cell (and thus the general circulation), and since the deep convection in the tropics is probably correlated with ionospheric potential, this research may lead to a means of quantifying the driving force for the general circulation with fine time resolution through ionospheric potential measurements as well as through analysis of satellite imagery.

C. PLANS FOR FY-85:

We hope in 1985 to expand our data base to include imagery from the Eastern GOES (which we already have acquired) plus the European METEOSAT, and the Japanese weather satellite in a continuation of the investigation.

D. RECOMMENDATIONS FOR NEW RESEACH:

The possibility of measuring the Hadley Cell intensity through analysis of satellite imagery and testing whether ionospheric potential measurements can be used for this purpose is recommended as an extension of the ongoing project.

E. LIST OF PUBLICATIONS PREPARED SINCE JUNE 1983: by Ralph Markson

1. Comments on Measurement of the Global Circuit and the Hy-Wire Potential Variations at Wallops Island, J. Geophys. Res., 89 (in press).

2. Measurement of the Global Circuit, to be presented at VIIth International Conference on Atmospheric Electricity, Albany, N.Y., June 1985 (preprint form now--to be published).

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Title: Statistical Structure of Convective Periods Derived from Satellite and Ground Based Data

Investigators: Paul J. Meyer
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Research Goals:

Statistical structure and correlation functions serve to quantify the nature of patterns that an analyst sees in the data but about which has only qualitative feelings. They also provide a measure of random error that is not dependent on comparisons against other sources of information. Our goal is to document the characteristics of VAS soundings through use of these statistical tools.

Significant Accomplishments to Date in FY-84:

Our basic methodologies were developed and tested on radiosonde data during the AVE-SESAME I period (10-11 April 1979). This phase was completed during FY-83. During FY-84, we submitted a manuscript to Monthly Weather Review that describes these activities. The proposed article was conditionally accepted subject to revision. A modified version was recently re-submitted, and we are now awaiting the outcome of the review process.

The AVE-SESAME I period provided rawinsonde data at 250 km separations; however, VAS retrievals are frequently at an even closer separation. Thus, several months of FY-84 were spent analyzing rawinsonde data from the AVE-SESAME V case (20-21 May 1979) in which the station separation was 75 km. Based on these results, modifications to our original procedures were prepared.

The bulk of this year has been devoted to investigating the AVE-VAS II period (6-7 March 1982). Structure and correlation functions are being used to compare VAS retrievals obtained using a physical algorithm (NESS/Univ. of Wisconsin) with those from a regression technique (NASA/Goddard). Results from both procedures are evaluated against those from a special mesoscale network of rawinsonde stations that was operated during the AVE-VAS Field Experiment. The parameters being documented include temperature, mixing ratio, geopotential height, thickness, and precipitable water. Calculations were performed at several levels (or layers) in the lower and upper troposphere.

Results indicate that both forms of satellite retrievals generally yield weaker horizontal gradients than those from the sondes. For example, Fig. 1 shows that slopes of the satellite-derived structure curves for temperature at 300 mb are smaller than those from radiosondes; this indicates the smaller gradients. Anisotropic calculations also are being performed. Figure 2 shows that 300 mb heights are highly anisotropic, with gradients maximized along a northeast-southwest direction. However, results from the three data sets are comparable; thus, each portrays the mean directional gradients in a similar manner. A final type of calculation permits random errors to be estimated. Depending on the level and parameter, errors in the VAS retrievals are comparable, or only slightly greater than those from radiosondes. Signal-to-noise considerations are favorable for the VAS data.

Focus of Current Research Activities:

We are making final calculations on the AVE-VAS II case. Specifically, RMS errors are being removed from the structure and correlation curves. As a result,

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systematic gradient differences between the data sources can be accurately determined, and maximum distances allowable for data interpolation can be assessed.

A major focus is report preparation. We have just submitted an article for the upcoming Conference on Satellite Meteorology. In addition, Paul Meyer is preparing his Master's thesis that will describe these efforts in greater detail. This thesis will be submitted to NASA for publication.

Plans for FY-85:

Results of the AVE-VAS II period will be condensed into a journal manuscript and submitted to the Journal of Climate and Applied Meteorology. In coordination with our other NASA contract, we will begin to investigate the physical retrieval procedure from first guess to final soundings. We will utilize data from AVE-VAS II; however, a much larger area will be considered than before.

Recommendations for New Research:

Convection was very limited during all of the 1982 AVE-VAS Demonstration days. Ground truth studies for pre-convective environments are needed to fully evaluate VAS's potential to aid in severe storm forecasting.

Publications Since June 1983:

Fuelberg, H. E., and P. J. Meyer, 1984: An analysis of the AVE-SESAME I period using statistical structure and correlation functions. Conditionally accepted for Mon. Wea. Rev.

Meyer, P. J., and H. E. Fuelberg, 1984: Structure function analyses of mesoscale VAS retrievals. Preprints Conf. on Sat. Meteor./Remote Sensing and Applications, In press.

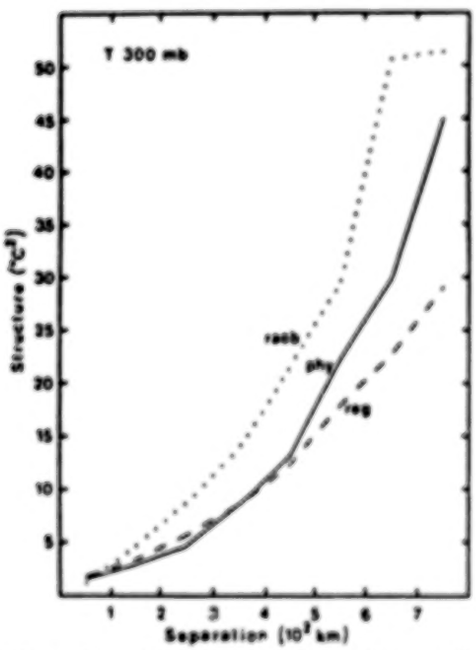

Fig. 1. Structure functions of temperature at 300 mb from regression (reg), physical (phy) and rawinsonde (raob) data.

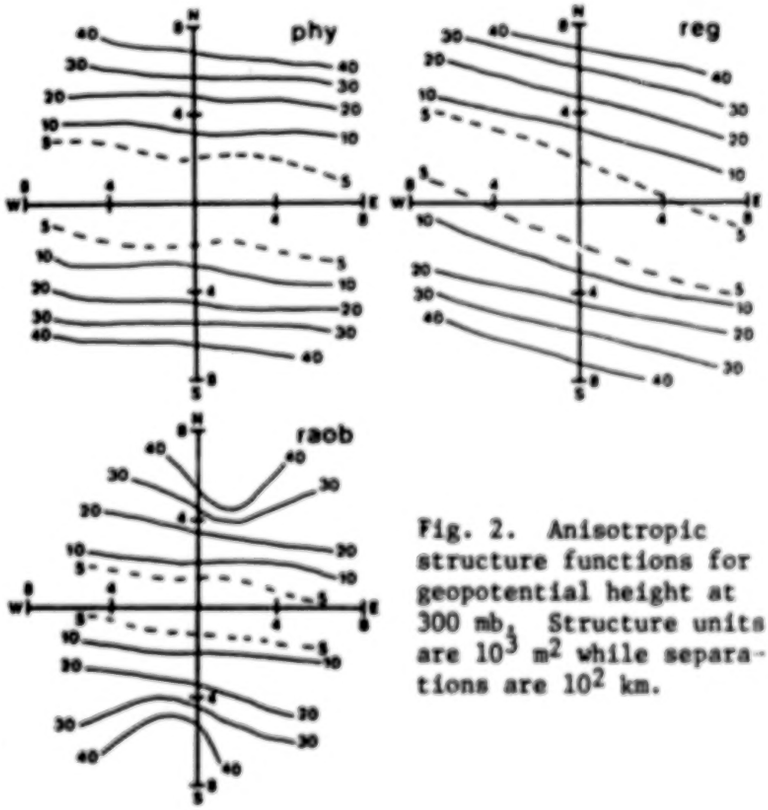

Fig. 2. Anisotropic structure functions for geopotential height at 300 mb. Structure units are 10^3 m^2 while separations are 10^2 km.

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TITLE: INVESTIGATION OF MESOSCALE PRE-CONVECTIVE FORCING MECHANISMS

RESEARCH INVESTIGATOR: Richard T. McNider
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SIGNIFICANT ACCOMPLISHMENTS FY84:

A numerical mesoscale boundary layer model was installed and tested on the MSFC-ASD Perkin-Elmer computer system. A graphics driver utilizing the NCAR graphics package was also developed allowing cross-section and plan view depictions of model predictive fields. The boundary layer model output was also linked to ASD's general data management and analysis system MASS. Such a link allows direct comparison of model predictions with AVE-VAS ground truth data as well as potential comparison with VAS temperature and moisture fields.

The basic purpose of the current investigation was to diagnose the physical mechanisms leading to the development of an organized convective line during AVE-VAS IV (April 24, 1982). A data analysis was first made using the special rawinsonde network which showed a strong baroclinic zone developing in the region where convection was initiated (Figure 1). The observed wind field showed an easterly component developed in opposition to the synoptic flow producing convergence.

The numerical boundary layer model was used to diagnose the physical development of the above described thermal and flow fields. Two candidate physical mechanisms were examined: 1) topography and 2) cloud shading. The models were run in varying combinations including topography, without topography, with cloud shading, without cloud shading, etc.

The model results showed that while heated sloping topography alone did create a modest baroclinic zone and convergence values; cloud shading was apparently a stronger mechanism for producing a thermal field representative of observed conditions. Significant convergence values were associated with the cloud shading case which, based on sensitivity tests with a two-dimensional cloud model, could have sustained convection. Figure 2. shows the model predicted thermal and flow field for the case with cloud shading and topography which can be compared to observations in Figure 1.

CURRENT FOCUS OF RESEARCH

Present work is directed toward a three-dimensional simulation of the case outlined above to provide a clearer understanding of the organization of the convective line in terms of topography and cloud shading. Attention is also being directed toward the role of accelerations in the velocity field due to frictional reduction as the boundary layer stabilizes.

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RECOMMENDATIONS FOR FUTURE RESEARCH

As shown in this study boundary layer forcing can play a major role in determining the pre-convective environment. A numerical model can assist in diagnosing this role; however, better parameterization is needed for cloud shading effects. Dynamic feed-back of latent heating is also required to extend model simulation into the convective phase. Additional evaluation of boundary layer forcing for other test cases is needed, especially nocturnal convection cases.

PUBLICATIONS:

R. T. McNider, G. Jedlovec, G. Wilson, 1984: Data analysis and model evaluation of the initiation of convection on 24 April 1982. Tenth Conference on Weather Forecasting and Analysis, AMS, Tampa, FL

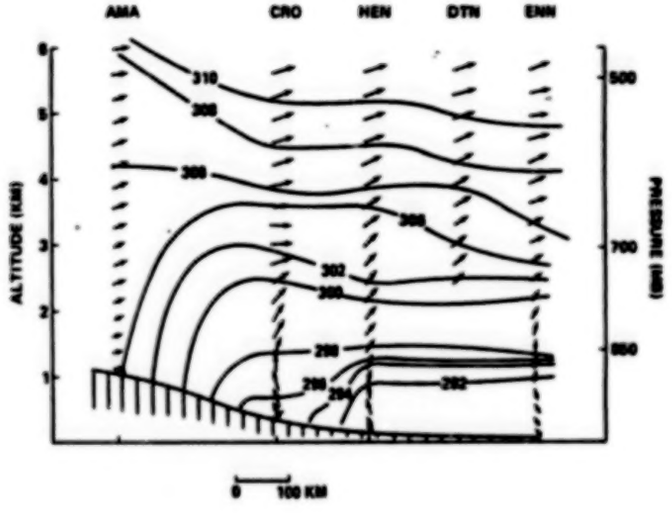

Figure 1. Cross-section analysis of potential temperature and horizontal winds. Cross-section runs from Amarillo along the Texas-Oklahoma border utilizing special network stations operating during AVE-VAS IV. Time is 2300Z. Contour interval is 2°K.

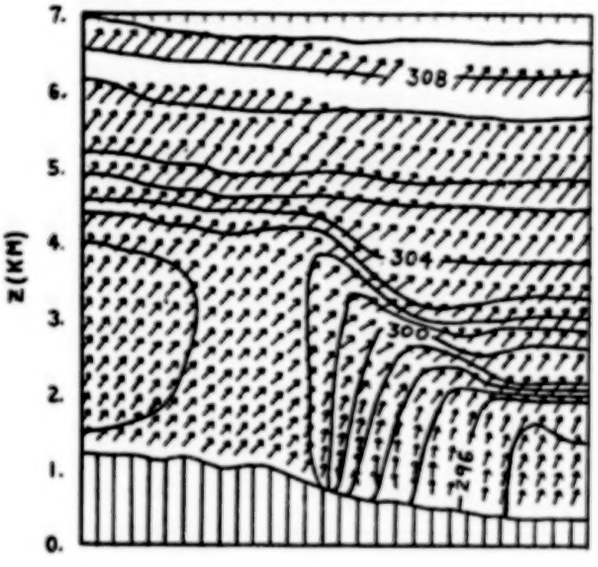

Figure 2. Cross-section of modeled temperature and winds employing cloud shading and topography as forcing functions. Time is 2000Z. Contour is 1°K.

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SUMMARY OF RESEARCH ACTIVITIES

TITLE: LAMPS Software

Research Investigators Involved:

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Significant Accomplishments to Date in FY-84:

The dynamic prediction model along with its macro-processor capability and data flow system from the Drexel Limited-Area and Mesoscale Prediction System (LAMPS) have been converted and recoded for the Perkin-Elmer 3220. The previous version of this model was written for Control Data Corporation (CDC) 7600 and CRAY-1a computer environment which existed until recently at the National Center for Atmospheric Research (NCAR). The purpose of this conversion is to prepare LAMPS for porting to computer environments other than that encountered at NCAR.

Focus of Current Research:

The revised model system is currently being tested in preparation for porting to both NCAR's current Cray-1a environment and the CDC 205 vector computer. Thus, the emphasis is shifting from programming tasks to model simulation and evaluation tests. During the near future the model system will be tested on real-data meteorological systems in support of the VAS Cooperative Project at the Marshall Space Flight Center.

Plans for FY-85:

Convert and recode the remaining programs in LAMPS for portability to other computer environments in support of the VAS Cooperative Project.

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Investigations of Arc Cloud Lines

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Research Objectives

This research is designed to provide in depth understanding of the natural mechanisms that lead to the development of deep convective storms through the integration of rapid scan satellite data with research aircraft observations. Previous research has shown that arc cloud lines and their associated convective scale interactions are of primary importance in determining the development and evolution of deep convection. In order to bring into sharper focus the dynamical and thermodynamical features of these arc clouds and convective interactions that lead to the development of deep (and often severe) convection, research aircraft flights were undertaken in Florida in the late summer of 1983. The aircraft measurements were designed to provide detailed air motion and thermodynamic data near and within the arc cloud line region at the same time GOES rapid scan data was being taken.

Significant Accomplishments

Seven research flights were made on five separate flight days. Each flight lasted between three and four and one half hours. On all but one of the flights, well-defined arc cloud lines were encountered, and penetrations were made within the density surge line (DSL) region from approximately 120 meters AGL to 650 meters AGL.

Preliminary inspection of the data (support was provided only for the flight phase) indicates:

1) Arc cloud lines are important in both the (a) production of convergence and vorticity, and (b) in the interaction with intense thunderstorms which may act to trigger tornado activity.

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2) The lateral extent of the vertical motion field compared to the cloud scale indicates that the main driving force for the initial cloud development along the arc-line is controlled by the thunderstorm outflow (s) interacting with the convectively unstable air of the environment. The individual cumulus cloud scale motions along the arc line can then be visualized as being superimposed on this somewhat larger-scale, initiating process.

3) Arc cloud lines and their associated DSL region can pose extreme hazards to aircraft operations. Depending on aircraft speed prior to its descent into the DSL, the loss of relative flow across the wing in the DSL can cause critical sink rates which may lead to an aircraft accident.

4) An arc cloud line's major threat to space shuttle operations lie in its ability to generate new thunderstorm activity along the shuttle glide path in time frames that occur after the decision for reentry has been made. Additionally, lateral wind shears across the runway could exceed shuttle landing requirements in either an arc cloud DSL environment or the environment of the thunderstorm it might have triggered.

Future Plans

1) Funding is needed to analyze the data sets so that the preliminary results indicated above may be quantified and the various convective scale interactions better defined.

2) The meteorological community is coming to realize the importance of outflow (arc cloud lines) in the production of rainfall as well as tornadic storm development. Scientists have proposed that the NASA Convair 990 equipped with a doppler lidar be used to investigate outflow and arc cloud lines. Our past experience in arc cloud investigations, as well as our ability to place an in situ platform in the region being sampled by the doppler lidar should be utilized in such an effort.

3) Investigations such as these should be included as a major part of SPACE.

List of Publications - "Conference"

Sinclair, P.C. and J.F.W. Purdom, 1984: Aircraft penetrations of arc cloud lines, 1st Conference on Satellite Meteorology/Remote Sensing and Applications, Clearwater, FL, Amer. Meteor. Soc., June 25-29, 4 pp.

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SPACE SCIENCE AND ENGINEERING CENTER

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Applications of the AVE-Sesame Data Sets to Mesoscale Studies

Researchers	Phone
V.E. Suomi	(608) 262-6172
Fred Mosher	(with NWS in Kansas City as of 4/84)
Carl Norton	(608) 263-2152
Robert J. Krauss	(608) 262-9523
David Suchman	(608) 262-5772
J.T. Young	(608) 262-6314

Addresses for all: 1225 West Dayton Street
Space Science and Engineering Center
University of Wisconsin-Madison
Madison, Wisconsin 53706

Significant events

1. BLM Lightning Data Concentrator

The system was installed in May 1983. Data was collected during the summer of 1983 and the equipment was removed in October of 1983. Data that were collected are available for research.

2. Mark III McIDAS

The Mark III McIDAS is installed and operating successfully. This capability provides greater flexibility for the Marshall user community and serves as a model of future UW McIDAS to remote computer links.

3. Design Study for a Three Dimensional Display Terminal

A number of display techniques have been investigated for the display of dynamic 3-D data sets. To date the most promising display technology is a polarized two CRT perspective display which allows both dynamic 3-D images and graphics presentations with full color capability. Algorithms for the preparation and display of conventional and satellite based weather data in 3-D have been developed. These include gridding, contouring, and streamlining processors which operate on both real time and case study data bases. An upper air trajectory model has been implemented which creates a display of air parcel trajectories in perspective 3-D. A subsystem for the generation of 3-D solid surface display with shading and hidden surface removal has been tested and its products are currently being evaluated. Motion parallax introduced by moving the point of observation during display is an important depth cue, which, when added to the perspective parallax has been found to create a very realistic appearing display.

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Current Research Activities

We are continuing the development or improvement of the various algorithms to achieve the maximum information content for the display of a variable. We are beginning the investigation of multivariant data displays, and combinations and correlations of vectors and scalars which we expect will finalize the meteorology display system specifications.

Plans for FY-85

We plan to refine our computer analysis and display algorithms, develop the stereo display terminal hardware specifications, and begin the testing and implementation of a terminal design tailored to this display concept.

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II.C.2. FIELD EXPERIMENTS AND SUPPORTING DATA ANALYSIS SYSTEMS

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TITLE: Satellite Precipitation and Cloud Experiment (SPACE)

RESEARCH INVESTIGATORS: James E. Arnold
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ED44
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Marshall Space Flight Center, AL 35812
(205) 453-2570

SIGNIFICANT ACCOMPLISHMENTS FY84:

An experiment plan has been formulated to support an investigation of the precipitation processes associated with mesoscale systems and the interaction of rain producing cloud complexes with the meso and macro-scale environment. The focal areas for this investigation are: 1) the structure and dynamics of precipitation systems, including the electrification and their relation to the multi-scale thermodynamic, and dynamic processes influencing the precipitation event, 2) the structure and dynamics of the moisture field about developing cloud and precipitation systems, 3) the scale interaction between the synoptic scale background and the meso/micro scale features leading to the production of significant precipitation events.

The field program necessary to accomplish the scientific goals is planned to take place in 1986. It is designed to incorporate satellite information (VIS and IR as well as VAS data), special radiosonde and surface observing capabilities, radar observations of storm development, special observations from aircraft and ground based lightning measurements. Both an increased understanding of the precipitation process and the use of meteorological satellite data in the analysis of precipitation events will result from this program. A significant contribution to the storm data base will also result from the special observation program.

The observing network required to accomplish the desired study of precipitation and related processes will consist of a special network of rawinsonde stations located in northern Alabama and eastern Tennessee. This network will have eight (8) RAWINSONDE stations at a spacing of approximately 100 km. The RAWINSONDE network is located over the western half of the Tennessee Valley Authority's special raingauge network. This network is supplemented by the climatological raingauge stations. In addition to the high density raingauge network, the network area is covered by the MSFC lightning location network. The inner core of rawinsonde stations will provide the "high resolution" observations necessary to investigate the finer details of the moisture structure surrounding the precipitation systems, as well as the precipitation characteristics. The larger scale features as well as the scale interaction problems will be investigated using the regular National Weather Service Network Rawinsonde stations in the southeastern portion of the United States. These observing stations will be supplemented by three (3) special stations in order to obtain a more nearly uniform grid over the area. Observations will be made at 3 hour intervals.

The rawinsonde network covering the southeastern US will provide the information to examine scale interaction as well as the broader aspects of

large precipitation regions such as are found in the spring of the year. The higher resolution network in northern Alabama/Tennessee will be operated for special portions of the larger scale studies but will be primarily used in a June-July study of the smaller scale precipitation events. It is anticipated that each network will have approximately 15 operational days, with the larger network operating primarily in the spring of the year and the high resolution network in the summer of the year.

CURRENT FOCUS OF WORK:

Current efforts are directed toward the development of the field program and the coordination of the observation requirements in order to accomplish the scientific goals of the experiment. The integration of the upper level observation program with capabilities of the surface research and operational radar observation is underway. The NASA U2 and ER2 aircraft programs will be coordinated with the observation program where mutual observational benefits are possible. Coordination with the operational requirements of the Microburst Severe Thunderstorm (MIST) program are being made to assure the most efficient utilization of the observing resources.

PLANS FOR FY85:

The development of the field program and the scientific goals will continue through the coming year. Although the observational phase of the program is planned to be in 1986, a significant portion of the procurement and experiment planning will be required to be carried out within the next year.

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OUTLINE OF RESEARCH ACTIVITIES

ANALYSIS OF SATELLITE DATA FOR SENSOR IMPROVEMENT
(Detection of Severe Storms from Space)

T. Theodore Fujita

The University of Chicago
Chicago, Illinois 60637
(312) 962-8112

Significant Accomplishments for FY-84

Item (1) Stereo photography of clouds over southeast Asia by using NOAA7 (U.S. satellite) and GMS (Japanes satellite)

Item (2) Lear Jet Expe iment based at Grand Island, Nebraska

Item (3) IR field of the thunderstorm which induced the Andrews AFB microburst. The IR temperature field was analyzed with 1°C accuracy. Results were presented at Andrews AFB and printed as SMRP Research Paper 205, December 1983, entitled "Andrews AFB Microburst".

Item (4) Planning of MIST (MIcroburst and Severe Thunderstorm)

Plans for FY-85

Item (1) Due to the breakdown of GMS II, GMS I, which had been retired, is being used as the replacement satellite. It is expected that GMS III will be launched this Summer so that the US-Japan stereo experiment can be activated again in Autumn 1984.

Item (2) The Lear Jet Experiment, 17-26 August 1983 was successful. Dates flown were:

Date	Liftoff(GMT)	Touchdown(GMT)	Hours flown	Remarks
Aug 19	2122:??	2313:20	1h 51m ??s	Test flight
Aug 21	2035:23	2252:17	2h 16m 44s	Redwood Falls clouds & Grand Island thunderstorm
Aug 23	2125:19	2333:00	2h 07m 41s	Anvil-top cirrus deck. "C"
Aug 24	2000:08	2210:39	2h 10m 31s	Circular thunderstorm
Aug 25	2108:15	2329:38	2h 11m 13s	Jumping cirrus. "C"

"C" denotes the Schedule C RDSS day arranged by NESS and requested by Fujita.

Flight cases are being analyzed in cooperation with Jim Arnold of MSFC, who is producing the high-resolution images of GOES West.

Item (4) The MIST Project at Huntsville, Alabama is being planned. The project will be conducted jointly with MSFC. Fujita will be securing from NCAR 2 to 3 Doppler radars and 55 PAM stations. MSFC will operate the upper-air networks. It is expected that rawinsondes will be launched every hour from MSFC during storm days.

Published Papers in FY-84

[1] Fujita, T.T. and J.C. Dodge (1983)
Applications of stereoscopic height computations from dual geosynchronous satellite data/Joint NASA-Japan stereo project. Ad. Space Res., Vol. 2, No. 6, pp. 153-160.

[2] Fujita, T.T. and R.M. Wakimoto (1983)
Microbursts in JAWS depicted by Doppler radars, PAM, and aerial photographs. Preprint Volume: 21st Conf. on Radar Meteorology, Sept 19-23, 1983, Edmonton, Alta., Canada, pp. 638-644.

[3] Fujita, T.T. and R.M. Wakimoto (1983)
JAWS microbursts revealed by triple-Doppler radar, aircraft, and PAM data. Preprint Volume: 13th Conf. on Severe Local Storms, Oct 17-20, 1983, Tulsa, OK, pp. 97-100.

[4] Smith, B.E. and B.R. Waranauskas (1983)
Analysis of wet microbursts by dual-Doppler and ground photography. Preprint Volume: 13th Conf. on Severe Local Stroms, Oct 17-20, 1983, Tulsa, OK, pp. 51-54.

[5] Fujita, T.T. (1983)
Andrews AFB microburst. SMRP Research Paper 205, Dec 1983, 38 pp.

[6] Stiegler, D.J.
Damage map of Hurricane Alicia, August 17-18, 1983.

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TITLE: Radar Analyses of Mesoscale Meteorological Phenomena During the AVE/VAS Correlation Field Experiment, NAS-8-34972.

Research Investigator: Dr. George L. Huebner
Department of Meteorology
Texas A&M University
College Station, Texas 77843
(409) 845-7647

Significant Accomplishments to Date in FY-84:

The principal portion of the research effort concerns the radar analyses of mesoscale meteorological phenomena during the AVE/VAS Correlation Field Experiment. The overall program consists of first, the collection of radar data during the selected critical times of the field experiment and, second, the subsequent analyses of the collected data for specific items.

Two radars were concerned with the collection of digitized data, the primary one being at Texas A&M University and the secondary set at the National Weather Service site at Stephenville, Texas. The initial portion of the effort concerned the selection of scan sequences, times of data collection and calibration procedures for both the Texas A&M radar as well as the NWS installation.

The analysis portion of the effort was divided among several tasks. A 400 Km by 400 Km grid set of 10 Km by 10 Km grids was established (with orientation with respect to true north at the Texas A&M radar) that covered the area for the AVE/VAS experiment. This placement allowed intense coverage of the southeastern quadrant by the Texas A&M University radar as well as near complete coverage of the 1600 grids by the NWS radar. No special vertical coverages were possible with the NWS radar in that they could not deviate from their normal collection routine.

The analyses of the radar data for the AVE/VAS experiment have provided statistically significant values for each of the 10 Km by 10 Km grids within radar range. It should be pointed out that approximately 1700 individual values were integrated for the average value for each grid area. The resulting information for correlation with satellite data included the following derived items that were averaged for each grid area.

(a) Rainfall rate in mm/hr
(b) dBZ (reflectivity) values
(c) Accumulated rainfall values per hour
(d) Accumulated rainfall values for a 6-hour period
(e) Vertically integrated liquid water content per square meter
(f) Vertical height of the radar axis at the midpoint of each grid

The data from the Texas A&M Radar have been analyzed and presented, in all cases, as taped information for the entire 1600 grid areas. In addition, one complete sequence has also been presented as Xerox computer plots of the information listed above.

In addition, there were subsets of data collected for a cooperative US Army program near Ft. Hood, Texas. In this case, an 11 by 11 subset of 10 Km by 10 Km grids was used as a basis for the collection of rainfall data at all times that any precipitation occurred within this subset area. This concerned a hydrological forecast study.

Focus of Current Research Activities:

Additional products derived from radar data are being investigated. An example of one such product is the derivation of the errors in integrated rainfall with different sampling periods. This is of significance for correlation with satellite data in that normally a "step-function" type of rainfall rate is used to derive the total rainfall over a period. The question arises when one asks just how often must one sample for a certain degree of accuracy.

Plans for FY-85 and Recommendation for New Research:

Work shall continue on the error analysis descussed above and, in addition, a proposal is being submitted to NASA for assistance in a pilot radar and satellite study of precipitation efficiency. In this case let us say that:

> Incremental liquid water content of a precipitating cloud EQUALS the incremental amount of water condensed MINUS a total of incremental amount evaporated and that amount that falls out as rainfall
>
> or
>
> If, in a typical case, e = 0.15 Condensate
>
> then
>
> Total LWC (over lifetime) = 0.85 total condensed — total rainfall
>
> or

$$\text{Efficiency} = \frac{\text{Total rainfall}}{\text{0.85 total condensate}}$$

The satellite data as well as rawinsonde data will assist in the determination of the evaporative portion of the equation.

List of Publications:

Arnold, J. E. and G. L. Huebner, "A composite look at a precipitating region using digital radar, GOES imagery, surface climatological rainfall data and 3-hour rawinsonde measurements," Conference on Satellite Meteorology/Remote Sensing and Applications, Clearwater Beach, Fla., 25-29 June, 1984.

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TITLE: Development of the Centralized Storm Information System (CSIS) for Use in Severe Weather Prediction

Research Investigators: Dr. Frederick R. Mosher, National Severe Storms Forecast Center, Room 1728 Federal Building, 601 E. 12th Street, Kansas City, Missouri 64106, FTS 758-3367.

A recent capability of CSIS is the display of radar data. The system is capable of ingesting and remapping radar scope presentations on a satellite projection. This can be color enhanced and superposed on other data types. Presentations from more than one radar can be composited on a single image. As with most other data sources, a simple macro establishes the loops and scheduling of the radar ingestions as well as the autodialing. There are approximately 60 NWS network 10 cm radars that can be interrogated. NSSFC forecasters have found this data source to be extremely helpful in severe weather situations. After thunderstorms have developed and matured, it is frequently difficult to locate the most intense thunderstorm cells using satellite data since there tends to be a considerable amount of cirrus "debris" associated with the cloud tops. The radar data complement the satellite picture and provide detail that would otherwise not be available. More experience with this new data source will be obtained with time so that even greater benefits should be realized. It has already proved helpful in severe weather diagnosis, watch preparation and clearance of watch areas no longer threatened.

The capability to access lightning frequency data stored in a National Weather Service computer in Boise, Idaho has been added. Currently, locations of lightning strikes can be displayed. Future plans call for more detailed analyses of these data to relate them to severe weather occurrences as well as increased display capabilities.

Future plans call for an interface with the National Meteorological Center (NMC) to receive and display prognostic fields from operational computer forecast models. Also, programs are to be developed to plot and display locations of reported severe local storm events.

In FY-85 VAS data will be accessed by the CSIS system. Further development of programs for display and analysis of the VAS data are planned.

List of Publications since June 1983:

"CSIS Test and Evaluation -- Final Report" by A.L. Siebers et al., unpublished report available at National Severe Storms Forecast Center, 70 pp.

"Use of CSIS in Severe Weather Prediction" by F.P. Ostby, Proceedings of Society of Photo-Optical Instrumentation Engineers Technical Symposium East '84, 6 pp.

II.C.3. SENSOR STUDIES AND ANALYSES

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TITLE: NSSFC VAS Assessment Activities

Research Investigators: Richard W. Anthony and Preston W. Leftwich, National Severe Storms Forecast Center, Room 1728 Federal Building, 601 E. 12th Street, Kansas City, Missouri 64106, FTS 758-5395.

Basic work thus far has been directed toward evaluating, over the past two springs and the current one, the VAS data in near real-time to determine its ability to detect regions with potential for severe storm development. During scheduled transparent VAS Mode (TVM), NSSFC via a McIDAS terminal maintains a real-time hourly water vapor loop 16 hours daily. These data are utilized operationally by the center's meteorologist to monitor position and trends of mid and upper level meteorological features. A specific finding has been that frequently because water vapor is more uniform than clouds the water vapor images improve our ability to monitor certain atmospheric features such as: jets, shortwaves, vorticity centers, and subsidence zones, etc.

The focus of our activities this spring will include our real-time evaluation of the VAS imagery and soundings processed by the ASPP unit at the University of Wisconsin. Additional products generated by the unit for our evaluation, include a version of the "split window" developed by NASA and cloud drift winds generated from three hourly sequenced CO_2 VAS channels. A technique also under evaluation at NSSFC provides hail size potential based on VAS sounding data.

Current plans call for an upgrade to CSIS by sometime in FY-85. Part of this upgrade will include removing our present McIDAS terminal and linking the 9600 baud phone line to one of the CSIS CPUs. This will allow access to VAS data via CSIS and should ease the job of forecaster familiarization. There are a number of logistical questions that will have to be resolved when this upgrade occurs.

Although current efforts at ASPP are directed toward processing soundings for synoptic regions, we recommend future work for the center also be directed toward providing soundings for mesoscale regions. In addition, the split window should become an operational tool by next severe storm season and assessment should be smoother.

Publications:

Anthony, R.W. and Leftwich, P.W., 1983: NSSFC VAS Assessment Activities for 1982/83. Unpublished report.

_____, Wade, G.S., 1983: VAS Operational Assessment Findings for Spring 1982/83, Preprints 13th Conf. on Severe Local Storms (Tulsa OK).

_____, Leftwich, P.W., 1983: Operational VAS Applications in Identifying Regions with Potential for Severe Thunderstorm Development, Preprints, Tenth Conf. on Weather Forecasting and Analysis (Clearwater, FL).

_____, Gird, R., 1983: The Use of Satellite Moisture Channel Pictures, Central Region Technical Attachment 83-10.

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N84 34892 D63

TITLE: A Statistical Evaluation and Comparison of VISSR Atmospheric Sounder (VAS) Data

RESEARCH INVESTIGATOR:

Gary J. Jedlovec
USRA Research Associate
Marshall Space Flight Center, ED-44
Huntsville, Alabama 35812
(205) 453-5532 or FTS 872-5532

SIGNIFICANT ACCOMPLISHMENTS:

An evaluation of VAS sounding data has been completed for one of the AVE/VAS field experiment periods. Three satellite sounding data setswere available for analysis on 6 March 1982 at five time periods (1100 GMT, 1430 GMT, 1730 GMT, 2030 GMT, and 2330 GMT). Three-hourly mesoscale rawinsonde observations were available over central Texas and Oklahoma with supporting three-hourly synoptic scale observations from the standard NWS network in the central part of the United States. In order to account for the temporal and spatial discrepancies between the VAS and rawinsonde soundings, special procedures were followed. The rawinsonde data were adjusted to a common hour of release where the new observation time corresponded to the satellite scan time. Both the satellite and rawinsonde observations of the basic atmospheric parameters (T, Td, and Z) were objectively analyzed to a uniform grid maintaining the same mesoscale structure in each data set. A detailed evaluation of the performance of each retrieval algorithm in producing accurate and representative soundings was performed using statistical parameters such as the mean, standard deviation, and root-mean-square of the difference fields for each parameter and grid level. Horizontal structure was also qualitatively evaluated by examining atmospheric features on constant pressure surfaces. An analysis of the vertical structure of the atmosphere was also performed by looking at co-located and grid mean vertical profiles of both the satellite and rawinsonde data sets. A few highlights of these results are presented below.

Table 1. indicates the mean difference and standard deviations of the differences between the rawinsonde and satellite gridded fields (RAO-SAT) for the composite of all five times. Time composite results are often misleading since biases and errors can cancel out to produce small composite results. In this investigation, large biases occured at several time periods, but are not accurately portrayed in the composite results shown below. Despite this problem, the composite results present some very interesting conclusions. Mean temperature differences between the satellite and rawinsonde data sets indicate a considerable warm bias in the composite results. The statistical scheme (Lee, et al., 1983) and the physical scheme (Smith 1970) indicate a bias which is maximized in the mid-troposphere whereas the modified physical scheme (Smith, 1983) a larger low level warm bias. Despite these bias differences, the standard deviation of the temperature differences are quite similar from one data set to another and fairly consistent in the vertical. Mean dew point temper-

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Regression (GSFC)

Pressure Levels	T (°C)		TD (°C)		PW (cm)		Z (m)		Thick. (m)		Grad T (°C/100km)		Grad Z (m/100km)	
100	0.6	0.7	---		---		-24.9	25.4	•		0.2	0.6	6.2	21.0
150	-0.2	0.7	---		---		-27.3	26.6	•		0.3	0.6	0.5	27.0
200	1.6	0.9	---		---		-36.8	27.3	19.2	17.4	0.3	0.8	-3.2	29.0
250	0.4	2.0	---		---		-44.1	27.7	•		0.1	1.0	-0.7	29.0
300	0.0	2.8	---		---		-43.6	30.9	•		0.3	1.2	6.0	28.0
350	-1.6	1.1	9.1	8.1	---		-37.4	31.2	•		-0.3	1.0	6.4	24.0
400	-1.6	2.4	1.2	4.8	---		-32.2	28.0	-27.3	16.0	0.5	1.4	5.0	19.0
450	-2.4	1.9	-1.1	3.1	---		-25.2	23.2	•		1.2	1.4	1.3	15.0
500	-2.4	1.9	-0.8	2.4	---		-16.9	18.3	•		1.0	1.3	-1.7	12.0
550	-1.7	1.4	-1.4	3.3	---		-11.2	15.0	•		0.7	1.1	-3.5	10.0
600	-0.4	1.2	-0.4	4.3	---		-8.4	12.2	-8.5	11.8	0.2	0.9	-4.5	8.7
650	0.2	1.1	-1.1	4.4	---		-7.8	10.2	•		0.1	0.7	-4.4	7.7
700	0.3	0.9	-1.5	3.3	---		-8.4	8.6	•		0.1	0.8	-3.8	7.0
750	0.9	1.0	-1.6	2.4	---		-9.8	7.8	•		0.3	0.9	-3.0	6.7
800	0.3	1.3	-2.7	1.7	---		-11.2	7.1	1.7	5.7	0.4	0.8	-1.5	6.6
850	-1.5	1.3	-3.4	1.5	---		-10.1	6.4	•		-0.1	0.7	-0.8	6.3
900	-3.2	1.3	-3.5	1.4	---		-5.7	6.1			0.0	0.8	0.0	5.6
SFC	0.4	1.4	1.0	2.3	0.6	0.9	---				0.5	0.9	---	

Physical (GRVHSR)

Pressure Levels	T (°C)		TD (°C)		PW (cm)		Z (m)		Thick. (m)	Grad T (°C/100km)	Grad Z (m/100km)
100	-2.4	1.1	---		---		-41.4	27.0			
150	-0.2	1.0	---		---		-44.4	23.8			
200	-0.1	1.3	---		---		-44.6	22.0			
250	-1.3	1.4	---		---		-42.4	21.0			
300	-1.7	1.6	---		---		-31.4	21.0			
350	-2.2	0.9	5.6	4.6	---		-19.4	20.0			
400	-1.7	1.4	4.0	3.6	---		-13.4	18.0			
450	-2.0	1.7	-0.8	4.8	---		-4.9	15.0			
500	-1.7	1.6	-2.4	4.5	---		-0.5	12.0			
550	-1.2	1.3	-4.4	5.0	---		2.4	12.0			
600	-0.4	1.1	-3.8	5.4	---		4.6	11.0			
650	0.3	1.0	-4.8	5.9	---		4.9	9.2			
700	0.4	1.1	-5.9	5.5	---		4.2	7.9			
750	0.8	1.1	-6.5	5.8	---		3.0	7.2			
800	0.5	1.0	-4.0	4.1	---		2.1	7.2			
850	-0.3	1.5	-2.0	2.3	---		1.3	6.8			
900	-0.5	1.4	1.3	1.4	---		0.5	5.7			
SFC	0.7	1.0	1.7	2.4	-1.0	1.6	---				

Modified Physical (VSOUND)

Pressure Levels	T (°C)		TD (°C)		PW (cm)		Z (m)		Thick. (m)		Grad T (°C/100km)		Grad Z (m/100km)	
100	0.0	0.9	---		---		-13.0	27.1	•		0.4	0.7	7.4	21.0
150	-0.1	0.7	---		---		-12.6	26.1	•		0.2	0.7	3.4	24.0
200	0.4	1.3	---		---		-14.5	24.2	17.3	17.4	0.5	0.8	0.7	23.0
250	0.4	1.1	---		---		-15.8	23.7	•		0.9	0.8	3.4	23.0
300	-0.6	1.7	---		---		-15.8	21.2	•		0.3	1.0	8.9	22.0
350	-0.4	1.1	---		---		-12.8	19.9	•		0.1	0.8	11.0	18.0
400	-0.1	1.4	1.1	5.1	---		-11.3	18.7	-36.1	14.4	0.7	1.2	7.9	16.0
450	-0.0	1.9	-0.3	4.3	---		-10.9	15.6	•		1.3	1.2	3.0	12.0
500	-0.3	1.9	0.9	4.8	---		-10.5	13.0	•		1.2	1.1	-1.0	10.0
550	-0.7	1.2	-1.3	5.0	---		-9.2	12.8	•		0.8	0.9	-3.2	8.7
600	-0.9	1.0	-1.7	4.2	---		-7.1	11.4	0.6	10.1	0.3	0.8	-4.0	7.5
650	-1.2	0.9	-2.9	4.8	---		-4.5	10.1	•		0.2	0.7	-3.3	6.8
700	-1.5	1.2	-4.1	5.3	---		-1.9	8.1	•		0.1	0.9	-1.7	5.8
750	-1.3	1.3	-4.4	5.1	---		0.7	6.5	•		0.3	0.9	0.3	4.8
800	-1.0	1.3	-4.4	4.8	---		3.0	5.0	5.8	6.6	0.3	0.9	2.6	4.2
850	0.1	1.3	-2.2	3.4	---		3.9	4.3	•		0.1	1.0	4.5	4.1
900	0.8	0.8	-0.9	2.1	---		3.0	3.1			0.3	0.7	4.1	4.4
SFC	-0.4	1.8	0.1	1.4	---		---				0.7	0.8	---	
			1.5	2.4	-0.6	1.2								

Table 1. Mean difference and standard deviations of the difference between rawinsonde and satellite gridded fields (Rao-Sat) for basic and derived parameters and for a composite of five times on 6 March 1982. Each Table represents the results for a different satellite retrieval scheme as labeled.

ature differences indicate large moist biases (RAO-SAT < 0) for the physical scheme in the lower and middle troposphere with magnitudes exceeding 5 °C near 700mb. The regression and modified physical schemes do not indicate such bias extremes in the composite results although at individual time periods (not shown) values can become quite large. The standard dew point deviations for all three satellite data sets are similar with values of about 2 °C in the lowest layers and 4-5 °C in the middle layers. Total precipitable water values also indicates that the physical schemes are both moist biased with standard deviations greater than 1.2mm while the regression scheme is some what dry biased.

Additional comparisonns for derived parameters of thickness, and the temperature and height gradients were calculated for the regression and modified physical schemes. Thickness comparisons for the two satellite data sets with the rawinsonde data are similar with mean thickness difference values about 30m too high in the 500-250mb layer. Standard thickness deviations both increase with decreasing pressure from the surface up to 100mb. Temperature gradient statistics indaicate that for the most part, the satellite soundings produce weaker thermal gradients with largest mean differences and standard deviations occuring in the middle and upper troposphere. Height gradient calculations indicate a weakened gradient in the upper levels but also a stronger height gradient in the lower levels. Futher analyses indicate that these stronger gradients occur where the rawinsonde fields indicate a weak gradient and the satellite error represented by the standard deviations significantly dominate the analyzed fields.

CURRENT AND FUTURE WORK:

Current efforts involve completing a rough draft of these findings for a journal article. The article will present a complete look at all three of the VAS sounding data sets for 6 March 1982. It is expected that this manuscript will be ready for submission this summer. Future plans at this time include further evaluations of VAS sounding data for the 24-25 April 1982 case. Soundings produced using a modified physical retrieval scheme are available at five times during the AVE/VAS experiment day.

PUBLICATIONS SINCE JUNE 1983:

1. A statistical evaluation and comparison of VISSR Atmospheric Sounder (VAS) data and corresponding rawinsonde measurements. NASA Technical Memorandom (in press), Marshall Space Flight Center, Huntsville, 1984
2. A statistical evaluation and comparison of VISSR Atmospheric Sounder (VAS) data and corresponding rawinsonde measurements. Preprints Satellite Meteorology/Remote Sensing & Appl. Conf., in press, AMS, Boston, June 1984.
3. MSFC special network statisical evalustion. (with Greg Wilson), VAS Demonstration Final Report, NASA Ref. Publ., in press, Goddard Space Flight Center, Greenbelt, Md., 1984.

References

Lee, T., D. Chesters, and A. Mostek, 1983: The impact of conventional surface data upon VAS regression retrievals in the lower troposphere. J. Appl. Meteor., 22, 1853-1874.

Smith, W. L., 1970: Iterative solution to the radiative transfer equation for the temperature and absorbing gas profile of an atmosphere. Appl. Opt., 9, 1993-1999.

Smith, W. L., 1983: The retrieval of atmospheric profiles from VAS geostationary radiance observations. J. Atmos. Sci., 40, 2025-2035.

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Prepared for
FY-84 Atmospheric Processes Research Program Review
May 2 and 3, 1984

Title: VAS Sounding Data Evaluation

Principal Investigator: Dr. James R. Scoggins
Department of Meteorology
Texas A&M University
College Station, TX 77843
409/845-7671

Significant Accomplishments to Date in FY-84:

A contract report has just been finalized which presents a comparison between the VAS soundings derived by NOAA personnel at the University of Wisconsin (UW) and NASA personnel at the Goddard Space Flight Center (GSFC), and rawinsonde soundings.

Three different types of comparisons between VAS and rawinsonde soundings were made. The first was a direct comparison between satellite and rawinsonde soundings plotted on Skew T-log p diagrams. The satellite sounding represents a highly smoothed version of the rawinsonde sounding; the satellite smoothing is both in the vertical and horizontal, but the vertical smoothing seems to be the more dominant feature.

Rawinsonde soundings were paired with the closest satellite soundings and the mean and standard deviations of differences between the two data sets were calculated. The profiles of temperature and dewpoint show mean differences of about 1.5°C and 3.0°C, respectively, with the standard deviations roughly constant with height. The differences are related to atmospheric structure and are dependent on synoptic and subsynoptic scale features that affect the variability of the rawinsonde (ground truth) profiles of temperature and moisture.

Satellite-rawinsonde differences for other parameters showed a strong dependence on the satellite profiles of temperature and moisture and can be explained by satellite vertical smoothing. The temperature differences show similar characteristics for both the UW and GSFC soundings, but statistical tests showed the two retrieval methods are producing statistically significantly different temperature profiles. The dewpoint differences between GSFC and UW show greater differences than the temperature profiles although the GSFC profiles were found to give a better representation of the ground truth. Statistical tests between satellite-rawinsonde differences show that at times corresponding to the greatest number of pairs, there is a statistically significant difference between the two data sets.

Synoptic and subsynoptic scale analyses were constructed with both rawinsonde and satellite data. Large scale systems are represented reasonably well by the satellite data with best analyses at higher levels. Small scale systems were poorly represented by the satellite data. The constant pressure charts show height and temperature fields that are highly smoothed compared to the rawinsonde. All but large scale features are lost in mesoscale vertical cross sections.

An analysis of temperature and height gradients showed that they would be poorly represented by the satellite data at low levels, but would improve with height and for this case it was not possible to accurately measure gradients over small distances (<200 km) with the satellite data.

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The results given here pertain to one synoptic situation in which there was a high degree of vertical structure in the temperature profile. The limitations of the satellite soundings for prescribing small scale horizontal features are directly related to the limited vertical resolution of the satellite sensor. This study demonstrates the need for a geostationary satellite sounder with higher vertical resolution.

Focus of Current Research Activities:

Now that we have achieved a reasonable understanding of the accuracy and representativeness of the VAS data, we have turned our attention to the utilization of the data. Our approach is to develop a method for combining the VAS and rawinsonde soundings into a unified data set that will preserve the large-scale features of the rawinsonde data and utilize the VAS data to add horizontal resolution. We hope this can be done for areas with and without rawinsonde soundings. If rawinsonde soundings do not exist as over the ocean, constant pressure charts will be utilized to determine characteristics large-scale features of the rawinsonde soundings. Once the unified data set is derived, geopotential heights will be recomputed, a method developed for deriving wind from the geopotential heights, and analyses conducted to determine the utility of the new data set in diagnostic analysis, specification of initial conditions, and in forecasting.

The initial approach in developing a unified data set, although barely begun before the present contract expires at the end of May 1984, is to combine the zeroth and first harmonics from rawinsonde data with the second and third harmonics from satellite data. Gridding procedures are used to match the two fields. Initial results are extremely promising. Over the VAS regional network, the one case analyzed so far shows improved horizontal resolution compared with rawinsonde data alone, and the measured winds appear to agree better with the height fields computed from the unified data than with the rawinsonde height fields. These are very preliminary results; much additonal research is required before conclusions are reached.

Plans for FY-85:

A proposal has been submitted to NASA for the continuation of this research. Our hope is to continue the research on the utilization of the VAS soundings. If funded, the research will concentrate on the development of a unified data set and its validation, and on utilization of the data.

Recommendations for New Research:

Our research on the accuracy and representativeness of the VAS soundings shows that additional vertical resolution in the VAS data is desirable. A study is needed to determine whether or not additional vertical resolution can be achieved by increasing the number of channels in the radiometer. Also, additional research is needed on the utilization of the VAS soundings. Research on this subject has barely begun.

Publications Prepared Since June 1983:

Townsend, Tamara L. and James R. Scoggins, 1983: The Influence of Convective Activity on the Vorticity Budget. NASA CR 3752, 105 pp.

Rhodes, Robert C. and James R. Scoggins, 1984: An Analysis of the Properties of VAS Satellite Soundings. NASA Contractor Report (In Publication), 104 pp.

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EVALUATION AND DEVELOPMENT OF NEW VAS REMOTE SENSING ALGORITHMS

William L. Smith, 1225 W. Dayton St., Madison, WI, 53706, (608)264-5325
W. Paul Menzel, 1225 W. Dayton St., Madison, WI, 53706, (608)264-5325

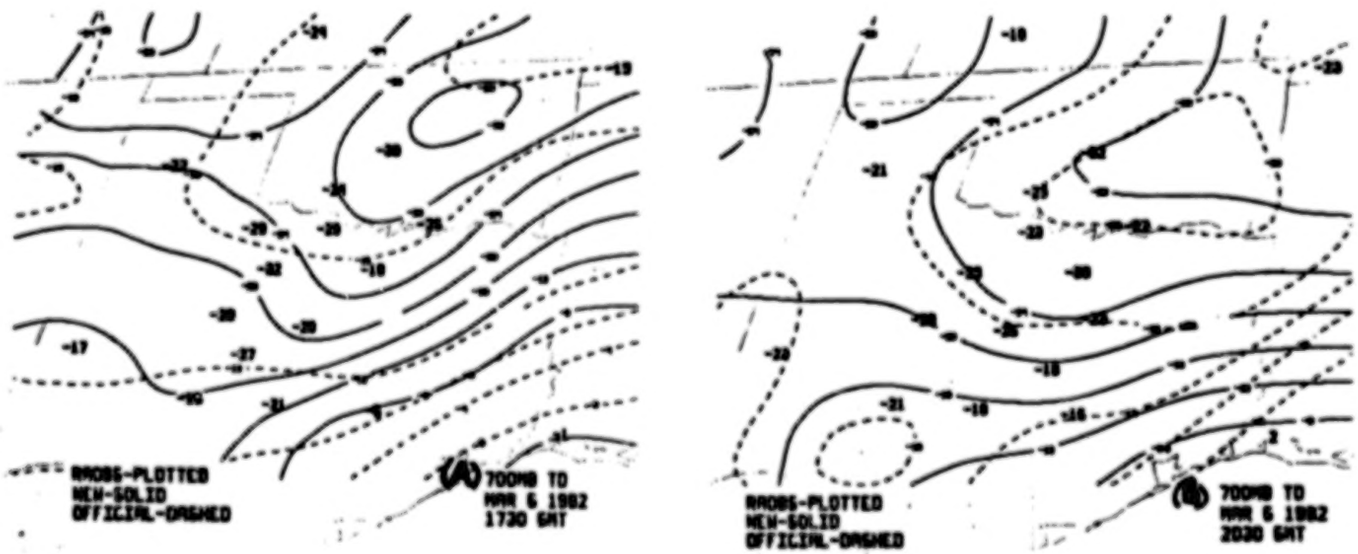
Introduction

This research is part of an ongoing program to improve VAS remote sensing capabilities through algorithm improvements and product refinements. The AVE/VAS data sets are used to evaluate potential improvements.

Accomplishments to Date in FY 84

During FY 84 a new physical algorithm has been developed to permit the simultaneous retrieval of temperature/moisture profiles and surface skin temperature by direct analytical solution of the radiative transfer equation. The new algorithm alleviates the problem associated with the interdependencies of water vapor retrieval on temperature retrieval and their dependencies on surface emissions. Simultaneous solution of all these quantities is achieved in one calculation using the available radiance observations; the previous algorithm achieved a solution only after several iterations. Since only a single matrix inversion is required for the specification of all parameters, the solution is computationally efficient. Ancillary observations of temperature and/or moisture from surface sensors on aircraft can be readily incorporated into the solution.

Simulation tests of the method indicate improved performance over the previous iterative technique, particularly for the lower troposphere and for water vapor. Fig. 1 shows a comparison of 700 mb dewpoint temperature analyses based upon the new method (solid) and the older "official" method (dashed) produced from two 6 March 1982 data sets separated by three hours. The AVE/VAS radiosonde observations are shown. One can see much closer agreement with radiosondes and better time continuity of the VAS moisture produced by the new retrieval method over older iterative method used to produce the "official" data set.



Focus of Current Research Activities

An attempt is being made to incorporate polar orbiting microwave observation in the profile retrieval process in order to achieve better spatial continuity of VAS sounding products. The use of 1 km resolution visible data to improve sounding retrievals under partial cloudiness is also being investigated.

Plans for FY-85

1. Completion of a fully amalgamated geostationary satellite (VAS) and polar satellite (MSU) sounding retrieval capability.

2. Development of algorithms to produce retrieval products (e.g., moisture and stability) at the full resolution of the VAS (7 km) for mesoscale applications.

3. Intercomparisons of VAS retrieved profiles with mesoscale vertical and horizontal resolution soundings to be obtained by the HIS interferometer and MAMS imager being tested aboard the NASA ER-2 aircraft.

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TITLE: Automated Mesoscale Winds Derived from Goes Multispectral Imagery

RESEARCH INVESTIGATORS INVOLVED: Gregory S. Wilson
ED44
Atmospheric Sciences Division
Marshall Space Flight Center, AL 35812
(205) 453-2570

Robert J. Atkinson
General Electric
Huntsville, AL 35805

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY84:

An automated technique for extracting mesoscale winds from sequences of GOES VISSR image pairs has been developed, tested extensively, and configured for quasi-real time/research applications on the Atmospheric Sciences Division's research computing system. This system is designed to give mesoscale wind estimates at the highest spatial/temporal resolution possible from the VISSR imagery down to a wind vector separation of 10 km. Major accomplishments have been made recently in three major areas:

1) Technique Development

Preprocessing of imagery using IR resampling, VIS edge-preserving filtering, and reduced VIS resolution averaging improves height assignments and vector extraction for 10, 15, and 30 min imagery.

An objective quality control system provides much greater than 99% accuracy in eliminating questionable wind estimates.

2) Diagnostic Evaluations

Comparisons of results with manually tracked winds are outstanding both statistically and structurally. Automated winds generally have better spatial coverage and density, and have random error estimates ($\sim$0.9 ms^{-1}) half as large as the manual winds.

Dynamical analysis of cloud wind divergence has revealed temporally consistent convergence centers on the meso-β scale that are highly correlated with on-going and future developing convective storms.

3) Real-Time/Research Testing

The entire system of computer codes was successfully vectorized for execution on an array processor resulting in job turnaround in less than one (1) hour.

Real-time/research data from the MSFC McIDAS can be directly inserted into the automated hardware/software system and results displayed and filed by McIDAS.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

A journal paper is under preparation describing the entire cloud winds systems including its application to a severe thunderstorm case.

A major improvement in the systems is underway involving the use of VAS imagery. Both "water vapor" winds and improved cloud height algorithms will be added to the current system and tested using special "rapid scan" VAS dwell imagery scheduled for acquisition from NOAA this spring.

PLANS FOR FY-85:

Integration, testing, and evaluation of the VAS multispectral imagery as part of the VISSR automated cloud wind system will be accomplished. These results will be submitted for journal publication, thereby ending this research activity. Assistance in utilization of technique by other institutions will also be offered (University of Wisconsin-Madison is currently installing the system.)

RECOMMENDATIONS FOR NEW RESEARCH:

Since this study has shown the need for high resolution multispectral imagery (in ∿ 8 spectral bands) at high time frequency (5-15 minutes), a feasibility study should be undertaken to examine the possibility of developing a dedicated Multispectral Atmospheric Mapping System (MAMS) for stabilized geostationary spacecraft for the purpose of mapping atmospheric structure and determining both mesoscale and global winds.

Use of these research results by other NASA researchers and other Government agencies, i.e., NOAA, should be encouraged.

PUBLICATIONS:

Wilson, G. S., 1984: Automated mesoscale wind fields derived from GOES satellite imagery. Preprints, Conf. on Satellite Meteorology/Remote Sensing and Applications, Clearwater Beach, FL (in press).

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67

TITLE: Sensor Studies and Space Flight Opportunities

RESEARCH INVESTIGATORS INVOLVED: Gregory Wilson
James Arnold
Franklin Robertson
Gary Jedlovec
Atmospheric Sciences Division
ED44
Marshall Space Flight Center, AL 35812

SIGNIFICANT ACCOMPLISHMENTS TO DATE IN FY-84:

Science issues, definition, instrument design studies, and hardware procurement for the Multispectral Atmospheric Mapping Sensor (MAMS) aircraft prototype, were all started and partially completed.

The science issues for a Shuttle Atmospheric Science Experiment (SASE) were defined around the precipitation processes question and results submitted and accepted for publication.

Mission science objectives and payload definitions studies for the Shuttle Earth Observation Experiment (EOM) mission series were begun.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

The SASE concept is being refined for final publication in the AMS Bulletin.

EOM science/mission definition studies are underway between MSFC and headquarters personnel.

MAMS aircraft hardware is under construction.

PLANS FOR FY-85:

MAMS engineering flights are anticipated in the fall of 1984 with science flights scheduled for the spring of 1985.

EOM science document will be prepared.

SASE instrument definitions studies will begin.

RECOMMENDATIONS FOR NEW RESEARCH:

The EOM Shuttle series should have a significant focus upon lower atmospheric as well as upper atmospheric and solar science issues. A lower atmospheric portion of the EOM series must be defined.

PUBLICATIONS:

Robertson, F. R., G. S. Wilson, H. J. Christian, S. J. Goodman, G. H. Fichtl, W. W. Vaughan, 1984: Atmospheric Sciences Experiments Applicable to Space Shuttle/Spacelab Missions (to be published in the AMS Bulletin)

APPENDIX A

OMIT TO END

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

GLOBAL SCALE PROCESSES RESEARCH PROGRAM
NASA/MSFC FY-84 ATMOSPHERIC PROCESSES RESEARCH PROGRAM REVIEW
BUILDING 4481, CONFERENCE ROOM 515
ATMOSPHERIC SCIENCES DIVISION

Monday, April 30, 1984

8:30 a.m.	WELCOME and INTRODUCTION	William W. Vaughan Robert J. Curran
8:45 a.m.	GLOBAL SCALE PROCESSES RESEARCH REVIEW OVERVIEW	George H. Fichtl
9:00 a.m.	GEOPHYSICAL FLUID FLOW CELL (GFFC) EXPERIMENT AND ASSOCIATED RESEARCH	John E. Hart Fred W. Leslie
9:45 a.m.	STUDIES OF BAROCLINIC INSTABILITY AT SMALL RICHARDSON NUMBER	Timothy L. Miller
10:00 a.m.	SYMMETRIC AND NONLINEAR BAROCLINIC INSTABILITY	Basil N. Antar
10:15 a.m.	THEORETICAL FLOW REGIME DIAGRAMS FOR AGCE	William W. Fowlis
10:30 a.m.	DOPPLER LIDAR AND BACKSCATTER ASSESSMENT OVERVIEW	Dan E. Fitzjarrald
11:15 a.m.	SATELLITE OBSERVATION OF TROPIC/SUBTROPIC MOISTURE COUPLING	Aylmer H. Thompson James P. McGuirk
12:00-1:00 p.m.	LUNCH BREAK	
1:00 p.m.	VARIATIONAL OBJECTIVE ANALYSES FOR CYCLONE STUDIES	Gary L. Achtemeier
1:45 p.m.	METEOROLOGICAL SATELLITE DATA RESEARCH AND APPLICATIONS & EFFECT OF LATENT HEAT ON GLOBAL WEATHER	John H. E. Clark
2:30 p.m.	SATELLITE DATA APPLICATIONS TO STUDY BAROCLINIC WAVES	Barry Saltzman Chung-Muh Tang

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3:15 p.m.	SOUTH PACIFIC CONVERGENCE ZONE (SPCZ) DURING FGGE, SOP I	Dayton G. Vincent Franklin R. Robertson
4:00 p.m.	UTILIZATION OF SATELLITE CLOUD INFORMATION TO DIAGNOSE THE ENERGY STATE AND TRANSFORMATION IN EXTRATROPICAL CYCLONES	Phillip J. Smith Franklin R. Robertson
4:45 p.m.	COMMENTS	Robert J. Curran John S. Theon William W. Vaughan

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

MESOSCALE PROCESSES RESEARCH PROGRAM
NASA/MSFC FY-84 ATMOSPHERIC PROCESSES RESEARCH PROGRAM REVIEW
BUILDING 4610 CONFERENCE ROOM 3053
ATMOSPHERIC SCIENCES DIVISION

Wednesday, May 2, 1984

8:30 a.m.	WELCOME and INTRODUCTION	William W. Vaughan James C. Dodge
	ATMOSPHERIC ELECTRICITY SESSION	
9:00 a.m.	PROGRAM OVERVIEW	Hugh J. Christian
9:10 a.m.	SUMMARY OF NIGHT/DAY SURVEY OF LIGHTNING CAPABILITIES	Bernard Vonnegut
9:30 a.m.	U-2 LIGHTNING RESEARCH PROJECT SYSTEM CAPABILITIES	R. Larry Frost
9:45 a.m.	SIMULTANEOUS OBSERVATION OF LIGHTNING FROM ABOVE AND BELOW CLOUD TOPS	Steve J. Goodman
10:05 a.m.	SOME OBSERVATIONS OF LIGHTNING FROM ABOVE	Marx Brook
10:25 a.m.	BREAK	
10:40 a.m.	ELECTRICAL AND OPTICAL CHARACTERISTICS OF LIGHTNING	E. Phil Krider
11:00 a.m.	ELECTRICAL ACTIVITY BENEATH SUPERCELL THUNDERSTORMS	Roy T. Arnold
11:20 a.m.	SEVERE STORM ELECTRICITY	W. David Rust
11:40 a.m.	REMOTE SENSING OF SEVERE STORMS	Richard E. Orville
12:00-1:00 p.m.	LUNCH BREAK	
1:00 p.m.	ATMOSPHERIC ELECTRICITY ACTIVITY ASSOCIATED WITH HURRICANE ALICIA	Richard L. Johnson
1:20 p.m.	MAXWELL CURRENTS AS A MEASURE OF THE ELECTRICAL ENERGY OF A THUNDERSTORM	Richard Blakeslee

1:40 p.m.	LIGHTNING MAPPER DEVELOPMENT-STATUS AND REQUIREMENTS	Hugh J. Christian

GROUND/AIRBORNE DOPPLER LIDAR WIND RESEARCH SESSION

2:00 p.m.	INTRODUCTION AND REVIEW OF RESULTS	Daniel E. Fitzjarrald
2:30 p.m.	RESULTS OF LIDAR/RADAR COMPARISONS	Richard J. Doviak
3:00 p.m.	RESULTS OF LIDAR WINDFIELD MEASUREMENTS NEAR SEVERE STORMS	Howard B. Bluestein
3:30 p.m.	RESULTS OF LIDAR WINDFIELD MEASUREMENTS OVER COMPLEX TERRAIN	William C. Cliff
4:00 p.m.	RESULTS OF GROUND-BASED LIDAR MEASUREMENTS	Jeffry Rothermel

Thursday, May 3, 1984

8:15 a.m.	OPENING REMARKS	William W. Vaughan
8:30 a.m.	RESULTS OF 1981 FLIGHTS APPLIED TO IMPROVEMENT OF LIDAR SYSTEM	James W. Bilbro
9:00 a.m.	RESULTS OF 1981 FLIGHTS APPLIED TO 1984/85 RESEARCH TOPICS AND FLIGHT PLANS	Daniel E. Fitzjarrald

MESOSCALE ANALYSES AND SPACE SENSOR SESSION

9:45 a.m.	PROGRAM OVERVIEW	Gregory S. Wilson

I. Fundamental Science

(The Mesoscale Environment)

10:00 a.m.	STATISTICAL ANALYSIS OF VAS RADIANCE AND SOUNDING DATA	Henry E. Fuelberg
10:20 a.m.	MESOSCALE ANALYSIS AND INTERPRETATION OF VAS IMAGERY/ SOUNDINGS	Gary J. Jedlovec
10:40 a.m.	EVALUATION AND DEVELOPMENT OF NEW VAS REMOTE SENSING ALGORITHMS	W. Paul Menzel

11:00 a.m.	AUTOMATED MESOSCALE WINDS DERIVED FROM VAS MULTISPECTRAL IMAGERY	Gregory S. Wilson
	(Mesoscale Precipitation/Clouds)	
11:20 a.m.	MESOSCALE PRECIPITATION STRUCTURE IN OCEANIC CYCLONES FROM MICROWAVE RADIOMETRY	Kristina Katsaros
11:40 a.m.	MESOSCALE CLOUD STRUCTURE AND THE DEVELOPMENT OF ORGANIZED CONVECTIVE PRECIPITATION	James Purdom
12:00-1:00 p.m.	LUNCH BREAK	
	(Mesoscale Modeling and Scale Interaction)	
1:00 p.m.	INITIALIZATION AND SIMULATION OF MESOSCALE BAROCLINIC CIRCULATIONS USING A HYBRID MODEL	Thomas Black
1:20 p.m.	REGIONAL-SCALE NUMERICAL SIMULATIONS OF ATMOSPHERIC STRUCTURE USING VAS DATA	George Diak
1:40 p.m.	A NUMERICAL SIMULATION OF ORGANIZED MESOSCALE PRECIPITATION	Michael W. Kalb
2:00 p.m.	THE RESPONSE OF CLOUD-SCALE PROCESSES TO ORGANIZED MESOSCALE AND BOUNDARY LAYER FORCING	Richard McNider
II.	Field Experiments and Supporting Data Analysis Systems	
2:20 p.m.	INTERACTIVE ATMOSPHERIC DATA ANALYSIS SYSTEMS	J. T. Young
2:40 p.m.	CENTRALIZED STORM INFORMATION SYSTEM (CSIS)	Fred Mosher
3:00 p.m.	SATELLITE PRECIPITATION AND CLOUD EXPERIMENT (SPACE)	James E. Arnold
3:20 p.m.	MICROBURST AND SEVERE THUNDERSTORM (MIST) EXPERIMENT	Ted Fujita
III.	Sensor Studies and Space Flight Opportunities	
3:40 p.m.	MAMS/SASE/EOM	Gregory S. Wilson
4:00 p.m.	U-2 LIGHTNING INSTRUMENT PALLET VISIT (Hugh Christian) DOPPLER LIDAR SITE VISIT (Dan Fitzjarrald) 3-D McIDAS DEMO (Greg Wilson)	

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APPENDIX C

Organizations Whose Sponsored Research Efforts
Are Included In The
FY-84 Atmospheric Processes Research Review

Airborne Research Associates, Inc.
Alabama A&M University
Atsuko Computing International
Battelle Northwest Laboratories
City College of New York
Colorado State University
Drake University
Drexel University
General Electric
Illinois State Water Survey
Institute for Atmospheric Optics & Remote Sensing
Lassen Research
Marshall Space Flight Center Space Science Laboratory
Marshall Space Flight Center Systems Dynamics Laboratory
National Severe Storms Forecast Center
National Severe Storms Laboratory, NOAA
New Mexico Tech
Purdue University
Roberts Associates, Inc.
Saint Louis University
South Dakota School of Mines
Southwest Research Institute
State University of New York at Albany
Texas A&M University
The Pennsylvania State University
The University of Alabama in Huntsville
Universities Space Research Association
University of Arizona
University of California
University of Chicago
University of Colorado

University of Illinois
University of Mississippi
University of Oklahoma
University of Tennessee Space Institute
University of Washington
University of Wisconsin
Yale University

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